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2018-1766, -1767

United States Court of Appeals for the Federal Circuit

TQ DELTA, LLC,

Appellant,

– v. –

CISCO SYSTEMS, INC., DISH NETWORK LLC, COMCAST CABLE COMMUNICATIONS, LLC, COX COMMUNICATIONS, INC., TIME WARNER CABLE ENTERPRISES LLC, VERIZON SERVICES CORP., ARRIS GROUP, INC.,

Appellees.

Appeals from the United States Patent and Trademark Office, Patent Trial and Appeal Board in Nos. IPR2016-01020, IPR2016-01021, IPR2017-00254, IPR2017-00255, IPR2017-00417, and IPR2017-00418.

JOINT APPENDIX

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TQ DELTA, LLC, Patent Owner/Appellant
v.
CISCO SYSTEMS, INC., et. al., Petitioners/Appellees

APPEAL NO. 18-1766, 18-1767

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Paper No. 41
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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

CLEMENTS, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
Inter Partes Review
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

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[1] DISH Network, LLC, who filed IPR2017-00254, and Comcast Cable Communications, LLC, Cox Communications, Inc., Time Warner Cable Enterprises LLC, Verizon Services Corp., and ARRIS Group, Inc., who filed IPR2017-00418, have been joined in this proceeding. Paper 14; Paper 15.

I. INTRODUCTION

In this *inter partes* review, instituted pursuant to 35 U.S.C. § 314, Cisco Systems, Inc. ("Petitioner") challenges claims 1–25 ("the challenged claims") of U.S. Patent No. 9,014,243 B2 (Ex. 1001, "the '243 patent"), owned by TQ Delta, LLC ("Patent Owner"). We have jurisdiction under 35 U.S.C. § 6. This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed below, Petitioner has shown by a preponderance of the evidence that the challenged claims are unpatentable. Patent Owner's Motion to Exclude is *dismissed*.

A. Procedural History

Petitioner filed a Petition requesting an *inter partes* review of claims 1–25 of the '243 patent. Paper 2 ("Pet."). Patent Owner filed a Preliminary Response. Paper 6. On November 4, 2016, we instituted *inter partes* review of claims 1–25 of the '243 patent under 35 U.S.C. § 103(a)[2] on the following grounds. Paper 7 ("Inst. Dec."), 16.

References	Claims
Shively[3] and Stopler[4]	1–3, 7–9, 13–16, and 20–22
Shively, Stopler, and Gerszberg[5]	4–6, 10–12, 17–19, and 23–25

[2] The Leahy-Smith America Invents Act, Pub. L. No. 112-29, 125 Stat. 284 (2011) ("AIA"), amended 35 U.S.C. §§ 102 and 103. Because the '243 patent has an effective filing date before the effective date of the applicable AIA amendments, we refer to the pre-AIA versions of 35 U.S.C. §§ 102 and 103.
[3] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011, "Shively").
[4] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012, "Stopler").
[5] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013, "Gerszberg").

Thereafter, Patent Owner filed a Patent Owner Response (Paper 12, "PO Resp."), to which Petitioner filed a Reply (Paper 17, "Reply"). Pursuant to an Order (Paper 21), Patent Owner filed a listing of alleged statements and evidence in connection with Petitioner's Reply deemed to be beyond the proper scope of a reply. Paper 22. Petitioner filed a response to Patent Owner's listing. Paper 29.

Patent Owner filed a Motion to Exclude (Paper 28), Petitioner filed an Opposition (Paper 33), and Patent Owner filed a Reply (Paper 37). Patent Owner also filed a Motion for Observation (Paper 27) to which Petitioner filed a Response (Paper 34).

We held a consolidated hearing on August 3, 2017, for this case and related Case IPR2016-01021, and a transcript of the hearing is included in the record. Paper 39 ("Tr.").

B. Related Proceedings

The parties indicate that the '243 patent is the subject of several district court cases. Pet. 1; Paper 5, 2–3; Paper 10.

C. The '243 patent (Ex. 1001)

The '243 patent discloses multicarrier communication systems that lower the peak-to-average power ratio (PAR) of transmitted signals. Ex. 1001, 1:26–29. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:36–40. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals. *Id.* at 2:40–43.

Figure 1 illustrates the multicarrier communication system and is reproduced below:

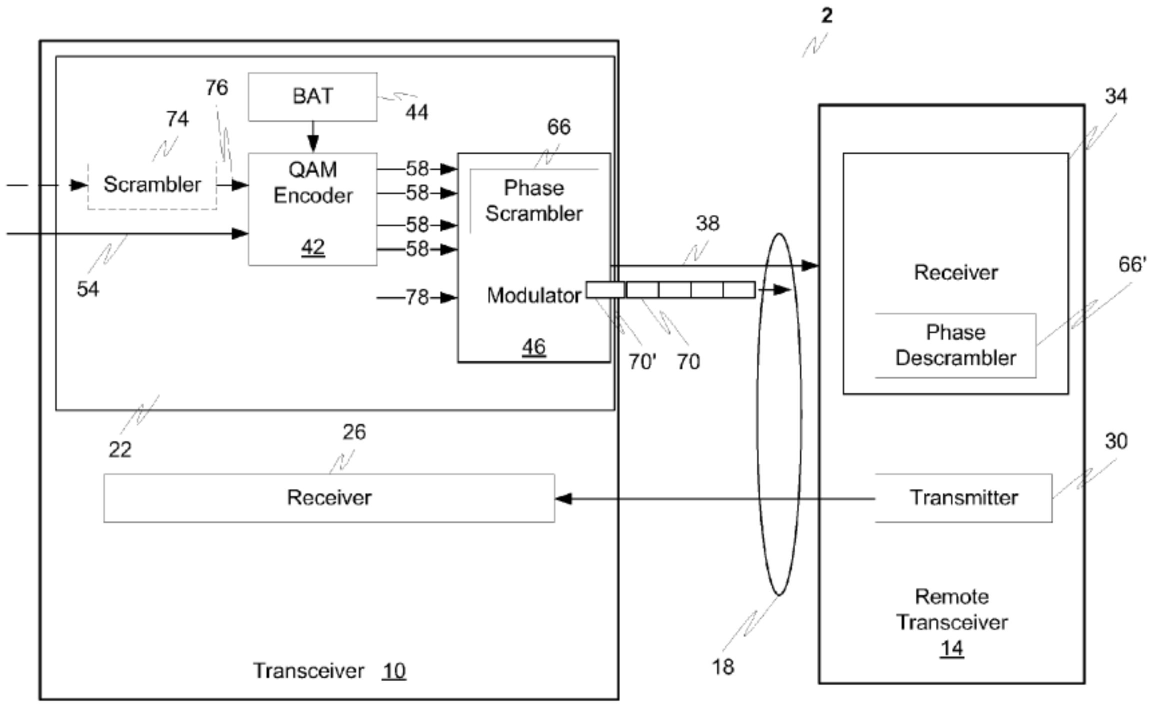


FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2 includes discrete multitone (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:25–29. DMT transceiver 10 includes DMT transmitter 22 and DMT receiver 26. *Id.* at 3:29–30. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:30–32. DMT transmitter 22 transmits signals over communication channel 18 to receiver 34. *Id.* at 3:38–41.

DMT transmitter 22 includes quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase scrambler 66. QAM encoder 42 has a single input for receiving serial data bit stream 54 and multiple parallel outputs to transmit QAM symbols 58

generated by QAM encoder 42 from bit stream 54. Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:10–13. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:13–16. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:29–32.

D. Illustrative Claims

Petitioner challenges claims 1–25 of the '243 patent. Pet. 8–52. Claims 1, 7, 13, and 20 are independent claims. Claims 2–6 depend from independent claim 1, claims 8–12 depend from independent claim 7, claims 14–19 depend directly or indirectly from independent claim 13, and claims 21–25 depend from independent claim 20. Claim 1 is illustrative of the claims at issue and is reproduced below:

> 1. A method, in a multicarrier communications transceiver comprising a bit scrambler followed by a phase scrambler, comprising:
>
> scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;
>
> scrambling, using the phase scrambler, a plurality of carrier phases associated with the plurality of scrambled output bits;
>
> transmitting at least one scrambled output bit on a first carrier; and
>
> transmitting the at least one scrambled output bit on a second carrier.

Ex. 1001, 10:58–11:4.

II. ANALYSIS

A. Claim Construction

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); *see Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2142–46 (2016). Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007).

1. "transceiver"

In our Decision on Institution, we construed "transceiver" to mean "a device, such as a modem, with a transmitter and a receiver." Inst. Dec. 6. Patent Owner contends that a construction is not necessary and cites a construction from a corresponding district court matter (Ex. 2007, 8), but does not argue we should adopt this construction. PO Resp. 13–14 ("Petitioners' arguments fail irrespective of which of the foregoing constructions for 'transceiver' is used."). Petitioner contends we should maintain our construction. Reply 7–8. Based on the record developed during this proceeding, we continue to apply this construction.

2. "scrambling . . . a plurality of carrier phases"

Independent claim 1 recites "scrambling . . . a plurality of carrier phases." Independent claim 7 similarly recites "scramble a plurality of carrier phases." Independent claims 13 and 20 similarly recite "scramble[s] a plurality of phases." Patent Owner argues that this language should be interpreted to mean "adjusting the phases of a plurality of carriers in a single

multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14–19. Petitioner argues that the phrase does not need to be interpreted, since the prior art relied upon uses the same "phase scrambling" terminology to describe pseudo-random phase changes. Reply 7 (citing Ex. 1012, 12:24–31). Additionally, Petitioner argues, without any other explanation, that "the Board should not adopt TQ Delta's proposed construction." *Id*. During oral argument, however, counsel for Petitioner reiterated that it is Petitioner's position that no construction of the term is necessary, because "[r]egarding patent owner's proposal of the construction, we believe that is exactly how Stopler is describing his phase scrambler as operating." Tr. 18:23–19:5.

Patent Owner argues that "scramble[e/ing . . . a plurality of carrier phases" and "scramble[] a plurality of phases" should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14. Patent Owner contends that the construction is supported by the Specification of the '243 patent and clarifies that the claimed phase scrambling "must be performed amongst the individual carrier phases in a single multicarrier symbol" and is not met if the phase adjustment only occurs over time from one symbol to the next. PO Resp. 14 (citing Ex. 2003 ¶ 37).

In support of its proposed interpretation, Patent Owner argues that the '243 patent describes that each of the plurality of carriers (of a multicarrier signal) corresponds to a different QAM symbol. PO Resp. 15 (citing Ex. 1001, 4:13–14). Patent Owner further argues that each carrier (or QAM symbol) has its own phase or phase characteristic, and that the combination of the carriers (or QAM symbols) is referred to as a DMT symbol. PO Resp. 16 (citing Ex. 1001, 4:7–9, 9:8–9; Ex. 2003 ¶ 39). Patent Owner further

contends that the ’243 patent describes that a “phase scrambler” scrambles phases or phase characteristics of carriers within a single DMT symbol, and that PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. PO Resp. 16 (citing Ex. 1001, 6:30–8:13; Ex. 2003 ¶ 39). PAR, Patent Owner contends, would not be reduced if carrier phases were only adjusted from one symbol to the next. PO Resp. 16 (Ex. 2003 ¶¶ 41–42).

Based on the record before us, we agree with Patent Owner’s proposed construction as far as meaning “adjusting the phases of a plurality of carriers in a single multicarrier symbol.” Patent Owner, however, provides no persuasive reasoning for also adding to that construction “by pseudo-randomly varying amounts.” Rather, Patent Owner merely contends that (1) in a corresponding district court matter, the court construed the phrase to mean “adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts;” (2) during prosecution of the ’243 patent, the applicant explained that a “scrambler” operates by pseudo-randomly selecting bits to invert; and (3) there was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristic of a carrier signal by pseudo-randomly varying amounts. PO Resp. 16–17 (citing Ex. 2007, 10–11; Ex. 2008, 18). Patent Owner’s explanation for why we should add “by pseudo-randomly varying amounts” to its proposed construction is conclusory. We interpret claims using the broadest reasonable construction in light of the specification of the involved patent. That standard is not the same as the standard used in district court. Patent Owner, however, provides no explanation for why we should apply the district court construction, which is not necessarily the same as used

before us, here. Moreover, the statement made during prosecution is in the context of summarizing an interview, purports to be part of a definition from Wikipedia, and is preceded by an "e.g." (Ex. 2008, 18). Patent Owner does not explain persuasively why this statement should be interpreted as disclaiming other possible forms of scrambling. In summary, Patent Owner's arguments are conclusory.

For all of the above reasons, and for purposes of this decision, we determine that "scrambling the phase characteristics of the carrier signals" means "adjusting the phases of a plurality of carriers in a single multicarrier symbol."

B. Level of Ordinary Skill in the Art

Petitioner contends that a hypothetical person of ordinary skill in the art, with respect to and at the time of the'243 patent, would have, "(i) a Master's degree in Electrical and/or Computer Engineering, or equivalent training, and (ii) approximately five years of experience working in multicarrier telecommunications," and that a "[l]ack of work experience can be remedied by additional education, and vice versa." Pet. 9–10. Patent Owner's expert, Dr. Short, agrees. Ex. 2003 ¶ 16 ("For purposes of this declaration only, I have adopted Dr. Tellado's definition of a person of ordinary skill in the art.")

We determine that the hypothetical person of ordinary skill in the art would have had either Master's degree in Electrical and/or Computer Engineering, or equivalent training, and approximately five years of experience working in multicarrier telecommunications. We note also that the prior art itself often reflects an appropriate skill level. *Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001) ("[T]he level of skill in the

art is a prism or lens through which a judge, jury, or the Board views the prior art and the claimed invention."); *Ryko Mfg. Co. v. Nu-Star, Inc.*, 950 F.2d 714, 718 (Fed. Cir. 1991) ("The importance of resolving the level of ordinary skill in the art lies in the necessity of maintaining objectivity in the obviousness inquiry.").

C. The Parties' Post-Institution Arguments

In our Decision on Institution, we concluded that the arguments and evidence advanced by Petitioner demonstrated a reasonable likelihood that claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively and Stopler, and that claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and Gerszberg. Inst. Dec. 16. We must now determine whether Petitioner has established by a preponderance of the evidence that the specified claims are unpatentable over the cited prior art. 35 U.S.C. § 316(e). We previously instructed Patent Owner that "any arguments for patentability not raised in the [Patent Owner Response] will be deemed waived." Paper 8, 6; *see also* 37 C.F.R. § 42.23(a) ("Any material fact not specifically denied may be considered admitted."); *In re Nuvasive, Inc.*, 842 F.3d 1376, 1379–1382 (Fed. Cir. 2016) (holding Patent Owner waived argument addressed in Preliminary Response by not raising argument in the Patent Owner Response). Additionally, the Board's Trial Practice Guide states that the Patent Owner Response "should identify all the involved claims that are believed to be patentable and state the basis for that belief." Office Patent Trial Practice Guide, 77 Fed. Reg. 48,756, 48,766 (Aug. 14, 2012).

With a complete record before us, we note that we have reviewed arguments and evidence advanced by Petitioner to support its unpatentability contentions where Patent Owner chose not to address certain limitations in its Patent Owner Response. In this regard, the record now contains persuasive, unrebutted arguments and evidence presented by Petitioner regarding the manner in which the asserted prior art teaches corresponding limitations of the claims against which that prior art is asserted. Based on the preponderance of the evidence before us, we conclude that the prior art identified by Petitioner teaches or suggests all uncontested limitations of the reviewed claims. The limitations that Patent Owner contests in the Patent Owner Response are addressed below.

D. Obviousness of Claims 1–3, 7–9, 13–16, and 20–22 over Shively and Stopler

Petitioner contends that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 10–42.

1. Principles of Law

A claim is unpatentable under § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations, including (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of skill in the art; and (4) when in evidence, objective indicia of non-obviousness

(i.e., secondary considerations). *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). We analyze this asserted ground based on obviousness with the principles identified above in mind.

2. Shively Overview

Shively discloses discrete multitone transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitone modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.*

at 10:29–30. The serial stream is segmented into N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

3. Stopler Overview

Stopler discloses a method and apparatus for encoding/framing a data stream of multitone modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67.

4. Petitioner's Initial Positions

Petitioner contends that a combination of Shively and Stopler would have rendered obvious claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent. Pet. 10–42. We have reviewed the Petition, Patent Owner's Response, and Petitioner's Reply, as well as the relevant evidence discussed in those papers and other record papers, and are persuaded that the record sufficiently establishes Petitioner's contentions for claims 1–3, 7–9, 13–16, and 20–22, and we adopt Petitioner's contentions discussed below as our own.

For example, the claim 1 preamble recites "[a] method, in a multicarrier communications transceiver comprising a bit scrambler

followed by a phase scrambler." Petitioner argues that the combination of Shively and Stopler disclose the preamble. Pet. 15–19. Petitioner argues that Shively discloses a "method for transmission in a multitone communication system," and Shively teaches the use of modems to transmit and receive communications. *Id.* at 15–16 (quoting Ex. 1011, 3:28–29; citing 9:42, 9:63–64, Fig. 2). Petitioner argues that Stopler discloses that "[m]ultitone modulation is a signal transmission scheme which uses a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel" and "[o]ne type of multitone transmission scheme is discrete multitone." *Id.* at 16–17 (quoting Ex. 1012, 1:42–49, 1:50–58; citing Ex. 1009, 31–32) (emphasis omitted). Petitioner further argues that Stopler discloses a transmitter that includes two scramblers, a bit scrambler and a phase scrambler. *Id.* at 18 (citing Ex. 1012, 9:34–37, Fig. 5; Ex. 1009, 33–34). We are persuaded by Petitioner's showing and find that Stopler's scrambler 56 is a bit scrambler and Stopler's QAM mapper and phase scrambler 82 is a phase scrambler.

Claim 1 further recites "scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits." Petitioner argues that Stopler discloses that "data output by the interleaver 54 is rearranged into a serial bit stream (MSB first) and then scrambled in scrambler 56, which is used to randomize the coded and interleaved data." *Id.* at 19 (quoting Ex. 1012, 9:34–48) (emphasis omitted). Petitioner argues that a person with ordinary skill in the art would have recognized that "Stopler's generating a randomizing sequence that is XORed with an input bit stream constitutes 'scrambling . . . a plurality of input bits.'" *Id.* (citing Ex. 1009, 35). We are persuaded by Petitioner's showing and find that

Stopler's scrambler 56 scrambles a plurality of input bits to generate a plurality of scrambled output bits.

Claim 1 also recites "wherein at least one scrambled output bit is different than a corresponding input bit." Petitioner argues that Stopler discloses that "the bits of the serial bit stream are 'scrambled in scrambler 56' to 'randomize' the data." *Id.* at 20 (citing Ex. 1012, 9:34–47). Petitioner argues that a person with ordinary skill would have recognized that "the XOR operation would result in at least one input bit to be changed when the corresponding bit in the randomizing sequence has a value of 1." *Id.* at 21 (citing Ex. 1009, 37). We are persuaded by Petitioner's showing and find that a person of ordinary skill in the art would have understood that, after Stopler's XOR operation, at least one scrambled output bit is different than a corresponding input bit.

Claim 1 additionally recites "scrambling, using the phase scrambler, a plurality of carrier phases." Petitioner argues that Stopler discloses that "the phase scrambler applies 'a phase scrambling sequence' to 'data in the form of m-tuples which are to be mapped into QAM symbols.'" *Id.* at 21 (quoting Ex. 1012, 12:20–28). Petitioner argues that Stopler discloses that "the phase scrambled symbols are provided to a modulator that performs signal modulation." *Id.* at 21–22 (citing Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 39–40). Petitioner further argues that both Shively and Stopler disclose "transmitting information by modulating multiple carrier frequencies." *Id.* at 22 (citing Ex. 1011, 8:3–13; Ex. 1012, 1:42–49, 1:50–61; Ex. 1009, 40). Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing and find

that Stopler's QAM mapper and phase scrambler 82 scrambles a plurality of carrier phases.

Claim 1 further recites "a plurality of carrier phases associated with the plurality of scrambled output bits." Petitioner argues that the combination of Shively and Stopler discloses that "the plurality of carrier phases are based on the symbols provided to the modulator" and Stopler further discloses "the symbols are mapped from m-tuple data . . . [where] the m-tuple data provided to QAM mapper and phase scrambler 82 are formed by processing the data output by the big scrambler 56 on an 'upper level' and a 'lower level.'" *Id.* at 23 (citing Ex. 1012, 9:48–55, 10:1–7, 10:40–11:50, 11:51–54, 12:20–22, Fig. 5; Ex. 1009, 42–43). We are persuaded by Petitioner's showing and find that the plurality of scrambled output bits are processed to become m-tuple data that is then "associated with" a plurality of carrier phases by QAM mapper and phase scrambler 82.

Claim 1 also recites "transmitting at least one scrambled output bit on a first carrier" and "transmitting the at least one scrambled output bit on a second carrier." Petitioner argues that Shively discloses determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream in at least a subset of those of the multitone subchannels." *Id.* at 24–25 (quoting Ex. 1011, 8:3–6, 8:5–13). Petitioner further argues that Stopler discloses "transmitting data bits by modulating the data bits on carriers using quadrature amplitude modulation (QAM) and multitone (multicarrier) modulation." *Id.* at 25 (citing Ex. 1012, 1:42–49, 12:20–28). Petitioner explains that it would have been obvious to a person with ordinary skill in

the art "to employ the techniques of Shively and Stopler to transmit at least one scrambled output bit that is provided to the modulator." *Id.* (citing Ex. 1009, 49). Petitioner further argues that Shively discloses transmitting a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 26–27. We are persuaded by Petitioner's showing and find that both Shively and Stopler teach transmitting at least one scrambled output data bit on a first carrier by modulating it using QAM.

Petitioner argues that "[i]t would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely a use of a known technique to improve a similar device, method or product in the same way." *Id.* at 13 (citing Ex. 1009, 26). Petitioner explains that a person of ordinary skill in the art would have recognized that "by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio" because "the overall transmitted signal in a multicarrier system is essentially the sum of its multiple carriers." *Id.* (citing Ex. 1009, 26). Petitioner asserts that a person of ordinary skill in the art "would have sought out an approach to reduce the [(peak-to-average power ratio)] PAR of Shively's transmitter" and "Stopler provides a solution for reducing the PAR of a multicarrier transmitter." *Id.* at 14 (citing Ex. 1009, 27). Petitioner argues that Stopler discloses "a phase scrambler [that] can be employed to randomize the phase of the individual subcarriers" (*id.* at 14 (quoting Ex. 1011, 12:24–28)) and "[a] POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same bits, but without those two subcarriers having the same phase." *Id.* at 14. Petitioner explains that "[s]ince the two subcarriers are

out-of-phase with one another, the subcarriers will not add up coherently at the same time," thereby reducing the peak-to-average power ratio (PAR) in Shively's system. *Id.* at 14–15. Accordingly, Petitioner argues that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." *Id.* at 15 (citing Ex. 1009, 28). Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing and find that Petitioner's articulated reasoning has sufficient rational underpinning to support the legal conclusion of obviousness. *See KSR Int'l Co.*, 550 U.S. at 418 (citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006)).

Petitioner performs a similar analysis for claims 2, 3, 7–9, 13–16, and 20–22. Pet. 28–42. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 1–3, 7–9, 13–16, and 20–22 are unpatentable as obvious over Shively and Stopler.

5. Patent Owner's Argument that Stopler Does Not Phase Scramble

Patent Owner contends that "Stopler must be compatible with single-carrier CDMA" (PO Resp. 59) based on Stopler's teaching that "[t]he framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 'Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System.'" Ex. 1012, 12:58–63; PO Resp. 29–30; *see also*

id. at 29–44 (arguing Stopler's framing scheme must be compatible with single-carrier CDMA). According to Patent Owner, "[b]ecause Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol." PO Resp. 59. Thus, concludes Patent Owner, "Stopler only discloses scrambling phases from one symbol[6] to the next symbol in time, and not with respect to multiple carriers in a single multicarrier symbol." PO Resp. 58–59; *see also id.* at 37 ("[i]t is nonsensical to scramble phases within a symbol because there is only one phase in each symbol.").

Patent Owner also relies on Stopler's claim 31 as corroboration for its position, contending that the phase scrambling performed by QAM Mapper and Phase Scrambler 82 "must at least be compatible with single carrier CDMA" because claim 31 is directed to a method in a "CDMA system" that includes the step of "phase scrambling." *Id*. at 33–34 (citing Ex. 1012, 16:4–48).

The "framing scheme" of Stopler is shown as a block diagram in Figure 5, reproduced below. Ex. 1012, 8:54–55 ("A block diagram of the framing scheme according to the present invention is shown in FIG. 5.").

[6] Patent Owner uses "symbol" to mean "a collective multicarrier symbol in a single symbol period (*e.g*. a DMT symbol)." PO Resp. 12. Patent Owner uses "carrier" to mean "a carrier symbol (*e.g*., a QAM symbol)." *Id.*

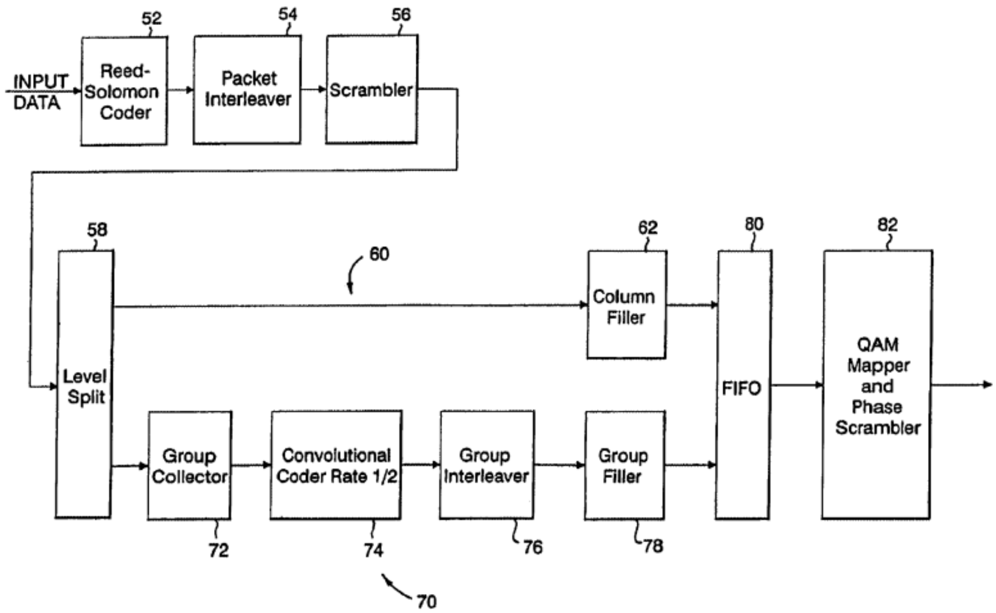
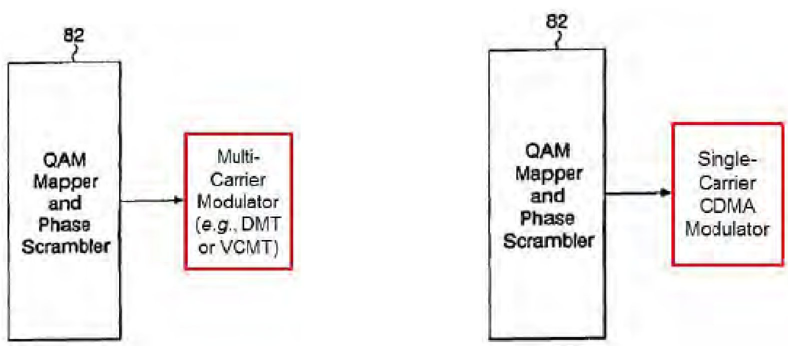


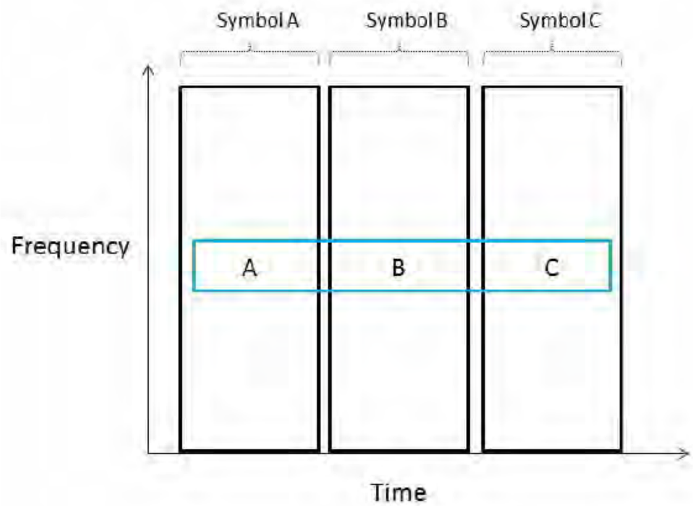
FIG. 5

To illustrate the use of Stopler's framing scheme with either a multicarrier modulator or a single carrier modulator, Patent Owner provides the following annotated excerpts of Figure 5:



PO Resp. 33.

We are not persuaded by Patent Owner's argument, which is based upon its assertion that "[s]ingle-carrier systems have only one carrier with only one phase" and, therefore, "[p]hase scrambling in a single-carrier system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box," in the figure reproduced below. PO Resp. 36–37.



Id. at 37. In this diagram, "Symbol A," "Symbol B," and "Symbol C" each represent a QAM symbol, not a DMT symbol, and each, according to Patent Owner, is phase scrambled relative to the other. Thus, Patent Owner's diagram shows only that a single-carrier embodiment of Stopler would transmit one phase-scrambled QAM symbol at a time. It does *not* show that QAM Mapper and Phase Scrambler 82 phase scrambles a DMT symbol—i.e., rotates, by the same amount, the phase of a plurality of QAM symbols. This is consistent with the cross-examination testimony of Patent Owner's expert, Dr. Short, who admitted that Stopler does not describe phase scrambling DMT symbols. Reply 17–18 (citing Ex. 1027, 60:11–14). Thus, Patent Owner's own diagram is consistent with Petitioner's position that Stopler phase scrambles individual QAM symbols, and Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol.

Whereas Patent Owner's position relies upon inference, Petitioner's position is supported by express disclosure in Stopler, which unambiguously

teaches "QAM symbols, for example, . . . 256-QAM" whose "constellation mapping may be the same as that used in ADSL." Ex. 1012, 12:20–24. Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id.* at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudo-random generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a *single* QAM symbol by that amount. Patent Owner, in contrast, identifies nothing in Stopler to suggest that QAM Mapper and Phase Scrambler 82 rotates the phase of a *plurality* of QAM symbols (e.g., every QAM symbol of a DMT symbol) by the same amount. Finally, we agree with Petitioner's argument that because "a CDMA modulator does not employ DMT symbols, . . . there is no reason for Stopler's phase scrambler to operate on DMT symbols," whereas "both DMT and CDMA modulators employ QAM symbols," so "applying the phase scrambler to individual QAM symbols [] is the only possible reading that is logically and technically coherent." *Id.* at 18–19 (citing Ex. 1026 (Tellado Reply Decl.) ¶ 58).

Patent Owner also argues that a person of ordinary skill in the art would have understood Stopler to be scrambling phase from symbol-to-symbol over time in order to reduce narrowband noise at the frequency of an

overhead pilot carrier. PO Resp. 39; *see also id.* at 38–44 (citing Ex. 2004 (U.S. Patent 6,370,156, "the '156 patent")). According to Patent Owner, "Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones." *Id.* at 40. We understand Patent Owner to be alluding to pages 12 to 13 of the Petition, which state

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26.

Pet. 12–13. In the claim-by-claim analysis of the Petition, however, Petitioner cites lines 20 to 28 of column 12, which include Stopler's teaching that "the phase scrambler is applied to all symbols, not just the overhead symbols." Pet. 21 (quoting Ex. 1012, 12:27–28). Thus, Petitioner is relying not just on the scrambling of "overhead signals, such as pilot tones," (Pet. 12) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive.

Finally, we are not persuaded by Patent Owner's argument that only its interpretation—i.e., adjusting the phase of an entire DMT symbol—would "simplify implementation," as Stopler teaches (Ex. 1012, 12:26), whereas Petitioner's interpretation would add complexity. PO Resp. 44 (citing Ex. 2003 ¶ 90). Patent Owner provides no explanation or analysis to support its conclusory assertions regarding simplicity and complexity, and the cited portion of Dr. Short's declaration merely repeats what is written in the Patent Owner's Response.

For the foregoing reasons, we are persuaded that Stopler teaches "scrambling, using the phase scrambler, a plurality of carrier phases," as recited in independent claim 1 and similarly recited in independent claims 7, 13, and 20.

6. Patent Owner's Assertions Concerning Reason to Combine

Patent Owner argues that the combined teachings of Shively and Stopler do not render obvious the challenged claims. PO Resp. 44. In particular, Patent Owner argues that (1) Petitioner provides no explanation for the "use of a known technique to improve a similar device" rationale to combine Shively and Stopler (*id*. at 45–47); (2) Petitioner wrongly claims that Shively's transmitter suffers from an increased PAR (*id*. at 47–49); (3) Petitioner's combination of Shively and Stopler suffers from hindsight (*id*. at 49–50); (4) there is no need to solve Shively's non-existent PAR problem (*id*. at 50); (5) Stopler does not reduce PAR in a multicarrier transmitter (*id*. at 51); (6) Stopler and Shively could not be combined (*id*. at 51–55); and (7) there were no "market forces" in effect to prompt Shively/Stopler combination (*id*. at 55–57). We address each argument in turn.[7]

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[7] Patent Owner lists several portions of Petitioner's Reply and evidence allegedly beyond the scope of what can be considered appropriate for a reply. *See* Paper 22. We have considered Patent Owner's listing, but disagree that the cited portions of Petitioner's Reply and reply evidence are beyond the scope of what is appropriate for a reply. Replies are a vehicle for responding to arguments raised in a corresponding patent owner response. Petitioner's arguments and evidence that Patent Owner objects to (Paper 22, 1–2) are not beyond the proper scope of a reply because we find that they fairly respond to Patent Owner's arguments raised in Patent Owner's Response. *See Idemitsu Kosan Co. v. SFC Co. Ltd.*, 870 F.3d 1376, 1381

a. Use of a known technique to improve a similar device rationale

Patent Owner argues that in making the contention that the combination of Shively and Stopler is a use of a known technique to improve a similar device, method or product in the same way, Petitioner fails to explain what is the known technique, what device/method/product is similar, and how is the alleged known technique used for improvement in the same way. PO Resp. 45–47.

In the Petition, Petitioner provides sufficient explanation regarding the reasons to combine Shively and Stopler. Pet. 13–15. The explanation provided in the Petition is not conclusory or confusing as Patent Owner asserts. The known technique is identified as phase scrambling. Pet. 14–15 (citing Ex. 1009, 27–28). The similar device is Shively's modem. Pet. 16. And the improvement to it is the same as in Stopler—to reduce PAR. Pet. 15 (citing Ex. 1009, 28–29).

b. Whether Shively's transmitter suffers from increased PAR and whether there is a reason to reduce PAR in Shively

Patent Owner argues that "Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather, Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic)." PO Resp. 47–49.

(Fed. Cir. 2017) ("This back-and-forth shows that what Idemitsu characterizes as an argument raised 'too late' is simply the by-product of one party necessarily getting the last word. If anything, Idemitsu is the party that first raised this issue, by arguing—at least implicitly—that Arakane teaches away from non-energy-gap combinations. SFC simply countered, as it was entitled to do.").

Patent Owner also argues that because Shively does not disclose a problem with PAR, one having ordinary skill in the art would have had no reason to look for a solution. PO Resp. 50. We are not persuaded by these arguments.

Specifically, Patent Owner argues Shively's system is unlikely to suffer from clipping[8] based on its analysis of a hypothetical 18,000 foot wire. PO Resp. 19–28. According to Patent Owner, the power of signals transmitted in Shively's proposed system would be "only 40% of maximum" in the normal mode for ADSL-1995 and "only 49% of maximum" in the power-boost mode of ADSL-1995. PO Resp. 19–28. Based on these figures, Patent Owner concludes that "the clipping probability for both normal and power-boost modes is virtually zero" because "[w]hile Shively's 'spreading' technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half." *Id.* at 28.

Petitioner argues that Dr. Short's analysis is flawed because (1) the teachings of Shively are not applicable only to 18,000 foot cables; and (2) Dr. Short "grossly underestimates the likelihood of phase alignment" in Shively because he wrongly assumes a Gaussian distribution. Reply 26–31. According to Petitioner, a proper analysis shows that Shively's techniques "significantly increases PAR and the likelihood of clipping." Reply 32–36 (emphasis omitted).

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[8] Patent Owner explains that, "[w]hen the maximum dynamic range of a component is exceeded, the signal will become distorted or will 'clip.'" PO Resp. 8. This is consistent with how the '243 patent uses "clipping." *See, e.g.*, Ex. 1001, 8:27–35.

We need not determine the exact probability of clipping in Shively's proposed system because, even assuming Patent Owner's analysis is accurate, it does not rebut Petitioner's reason to combine. Petitioner does not allege that Shively's proposed system causes clipping, or that a person of ordinary skill in the art would have been motivated to reduce PAR only if it caused clipping. Instead, Petitioner alleges that Shively's proposed system would have an "increased" or "high" PAR:

> A POSITA would have recognized that by transmitting redundant data on multiple carriers, *Shively's transmitter would suffer from an increased peak-to-average power ratio*. Ex. 1009, p. 26. This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. *Id*. When N subcarrier signals with the same phase are added together, they have a peak power which is N times greater than their individual maximum powers. *Id*.
>
> Since Shively's subcarriers use quadrature amplitude modulation (QAM) . . . transmitting the same bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. *Id*. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. *Id*. *Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time*. *Id*.

Pet. 13–14 (emphases added).

Patent Owner criticizes Petitioner's declarant for not providing "calculations or data that illustrate to what degree there is an 'increase' in PAR with Shively's transmitter" (PO Resp. 48), but we are not persuaded that such calculations and data are necessary. Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold. There is no dispute that transmitting the same data on multiple

carriers increases PAR (Reply 10 (citing PO Resp. 6–7; Ex. 2003 (Short Decl.) ¶ 22)) or that Shively's technique, specifically, will increase PAR (PO Resp. 28 ("Shively's 'spreading' technique will contribute a small uptick in clipping probability"). There also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR (Reply 37; Ex. 2003 (Short Decl.) ¶ 26; Ex. 1027 (Short Depo.) 45:21–19). Patent Owner's declarant, Dr. Short, testified that, given such issues, system designers or engineers would be interested in using techniques that could reduce PAR. Ex. 1027, 46:23–47:3. This is consistent with the reason to combine given in the Petition and supports Petitioner's position that "numerous problems" other than clipping "would have motivated a [person of ordinary skill in the art] to look for ways to reduce the PAR of Shively's technique." Reply 37.

In light of the foregoing, we are persuaded that a person of ordinary skill in the art would have recognized that Shively's technique would increase PAR and would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping.

c. Whether combination of Shively and Stopler suffers from hindsight

Patent Owner argues that only the inventor of the '243 patent recognized the problem of high PAR due to phase-aligned carriers. PO Resp. 49–50. Patent Owner argues that the only cited evidence that high PAR results from transmitting the same data on multiple carriers is from the '243 patent and that Petitioner "use[s] the '243 patent as a roadmap for arriving at their theory of obviousness" and "is a textbook case of impermissible hindsight bias." *Id*. We are not persuaded by this argument.

First, the portions cited in the ’243 patent in the Petition and in Dr. Tellado’s declaration come from the “BACKGROUND OF THE INVENTION” section of the patent. That portion of the ’243 patent uses words such as “conventional” indicating that what is described in the “BACKGROUND OF THE INVENTION” section is information that was known at the time of the invention, not just by the inventors, but persons of ordinary skill in the art. Patent Owner does not contend otherwise.

In addition, Dr. Tellado testified that a person having ordinary skill in the art would have recognized that the purpose of Stopler’s phase scrambler to randomize data symbols would be to reduce PAR of transmitted signals and that the person would have been familiar with the problems created by a high PAR, including PAR due to phase-aligned carriers. Ex. 1009 ¶¶ 60, 66. Moreover, Patent Owner’s own declarant recognized that PAR was a known problem at the time of the invention. Ex. 2003 ¶ 23 (“Conventional multicarrier systems, therefore, were designed to accommodate PAR.”). The ANSI T1.413-1995 standard also confirms that PAR was known at the time of the invention by describing that “[a] DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analog converter.” Ex. 1017, 36 (Section 6.5 “Tone ordering”). Based on the record evidence, we find that a person having ordinary skill in the art would have known about the problem of high PAR due to phase-aligned carriers.

d. Whether Stopler reduces PAR in a multicarrier transmitter

Patent Owner argues that Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-

carrier. PO Resp. 51. The argument is not persuasive for the reasons provided above.

e. Whether Stopler and Shively could be combined

Patent Owner argues that Shively and Stopler are incompatible and that it would not have been possible to incorporate Shively's bit-spreading concept into Stopler. PO Resp. 51. In particular, Patent Owner argues that Shively's bit-spreading concept is not compatible with Stopler's "diagonalization" technique. PO Resp. 51–55. This argument is misplaced as Petitioner did not rely on Stopler's "diagonalization" technique. Rather, Petitioner relies on Stopler's phase scrambler and scrambling technique. Pet. 14, 21–22. Moreover, Stopler describes its "diagonalization" technique as optional. Ex. 1012, 10:17, 13:1–3. For these reasons, we are not persuaded by Patent Owner's argument that it would not be possible to combine Shively and Stopler.

f. Whether "market forces" prompt Shively/Stopler combination

The Petition states that "[m]arket forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Pet. 15 (citing Ex. 1009, 28). Patent Owner argues that neither Petitioner nor Dr. Tellado identifies a single product or standard that employs any of the ideas disclosed in Shively or Stopler. PO Resp. 55–57.

Patent Owner's arguments are misplaced. It was not incumbent on Petitioner or Dr. Tellado to identify a product or standard that employs the

ideas disclosed in Shively or Stopler in order to show that the combination of Shively and Stopler would have been obvious to a person skilled in the art. That is not the standard. Rather, a claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR Int'l Co.*, 550 U.S. at 406. Dr. Tellado testified that a person having ordinary skill in the art would have been familiar with problems caused by a high PAR, that equipment needed to cope with PAR would have been expensive and inefficient, and that less capable equipment would have caused distortion such as from amplitude clipping. Ex. 1009 ¶ 66. He further testified that combining Shively's redundant bit transmission with Stopler's phase scrambling technique would have allowed for faster DSL modems without requiring more complex and expensive circuitry for handling increased PAR. *Id.* ¶ 69. Patent Owner has not presented sufficient evidence to undermine Dr. Tellado's testimony. Indeed, Dr. Short testified that a way to address high PAR in a communication system would be to use transceiver components that could handle higher peak transmission values, which would be expensive and power hungry. Ex. 1027, 45:15–46:12. Based on the record before us, we find that at the time of the invention, a person having ordinary skill in the art would have recognized that an increase in PAR would have been associated with more expensive communication equipment. Accordingly, a drive to reduce equipment costs would have motivated a person having ordinary skill in the art to include Stopler's phase scrambler into Shively's transmitter to reduce PAR. Pet. 13–15; Ex. 1009 ¶¶ 66–70.

7. Summary

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler.

E. Obviousness of Claims 4–6, 10–12, 17–19, and 23–25 over Shively, Stopler, and Gerszberg

Petitioner contends that claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 42–52.

1. Gerszberg Overview

Gerszberg discloses a telephone network interface unit typically disposed on the outside of a home or small business. Ex. 1013, 1:6–9. An intelligent services director (ISD) is placed near a customer’s premises for multiplexing and coordinating many digital services on to a single twisted-pair line. *Id.* at 2:12–23. A facilities management platform (FMP) is placed in the local telephone network’s central office for routing data to an appropriate interexchange company network. *Id.* A network server platform (NSP) is coupled to the FMP. *Id.*

2. Petitioner’s Initial Contentions

Petitioner contends that a combination of Shively and Stopler would have rendered obvious claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent. Pet. 42–52. We have reviewed the Petition, Patent Owner’s Response, and Petitioner’s Reply, as well as the relevant evidence discussed in those papers and other record papers, and are persuaded that the record sufficiently establishes Petitioner’s contentions for claims 4–6, 10–12, 17–

19, and 23–25, and we adopt Petitioner's contentions discussed below as our own.

For example, the claim 4 recites "[t]he method of claim 1, wherein the transceiver is a wireless transceiver," claim 5 recites "[t]he method of claim 1, wherein the transceiver is operable for high speed internet access," and claim 6 recites "[t]he method of claim 1, wherein the transceiver is operable to transport video." Petitioner argues that, as discussed above, the combination of Shively and Stopler renders claim 1 obvious. *See* Section II.B.3. Petitioner further argues that Gerszberg discloses the additional limitations of claims 4–6. Pet. 47–49. Petitioner explains that Gerszberg discloses a "transceiver [that] is 'coupled to a central office [] via a twisted-pair wire, hybrid fiber interconnection, wireless and/or other customer connection.'" *Id.* at 48 (quoting Ex. 1013, 2:67–3:9) (emphasis omitted). Petitioner also argues that Gerszberg discloses "'[h]igh-speed access to the Internet' and the 'ability to offer ultra fast Internet access.'" *Id.* (quoting Ex. 1013, 7:44–60, 8:16–24). Petitioner additionally argues that Gerszberg discloses "transporting 'video' and providing '[i]nteractive video teleconferencing.'" *Id.*at 49 (quoting Ex. 1013, 8:16–36, 10:63–11:3). We are persuaded by Petitioner's showing and find that Gerszberg teaches a wireless transceiver, a transceiver operable for high speed internet access, and a transceiver operable transport video.

Petitioner further argues that a person with ordinary skill in the art would have combined Gerszberg with Shively/Stopler "because Shively explicitly refers to Gerszberg and incorporates Gerszberg by reference." *Id.* at 43–44 (citing Ex. 1011, 18:7–9; Ex. 1013, 16:52–53; Ex. 1009, 69; *Telemac Cellular Corp. v. Topp Telecom, Inc.*, 247 F.3d 1316, 1329 (Fed.

Cir. 2001) (holding "[w]hen a document is 'incorporated by reference' into a host document, such as a patent, the referenced document becomes effectively part of the host document as if it were explicitly contained therein.")). Petitioner alternatively argues that "it would have been obvious to combine the teachings of Gerszberg with Shively and Stopler because the combination is merely the use of a known technique to improve a similar device, method or product in the same way." *Id.* at 44 (citing Ex. 1009, 69). Petitioner explains that both Shively and Stopler "describe transmitting data using DSL and multitone communication technologies" and a person with ordinary skill in the art would have recognized that DSL "was intended to provide data services such as high-speed internet and video to telephone subscribers." *Id.* (citing Ex. 1011, 1:5–8; Ex. 1012, 1:50–61, 9:37–41, 12:21–24, 12:55–57; Ex. 1009, 69). Petitioner argues that it was known that "Service Systems" that are offered by DSL technologies include "Internet access," "Interactive video," and "Videoconferenc[ing]." *Id.* at 44–45 (citing Ex. 1015, 100, 102, 104, Fig. 1). Accordingly, Petitioner argues, and we agree, that the "known technique for providing Internet and video services, as disclosed by Gerszberg, would be applied to the combination of Shively and Stopler to provide the advantage of addressing the market need for such services." *Id.* at 46 (citing Ex. 1013, 7:44–60, 8:16–36, 10:63–11:3).

Patent Owner argues that "Petitioners' assertion of unpatentability for the dependent claims . . . also falls short" for the same reasons argued above with respect to the independent claims. PO Resp. 59. We have addressed those arguments above, and, for the same reasons discussed above, are not persuaded. *See* Section II.D.5 and II.D.6.

3. Summary

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerzberg.

F. Patent Owner’s Motion to Exclude

Patent Owner filed a Motion to Exclude (Paper 28, “Motion”). Petitioner filed an Opposition to Patent Owner’s Motion (Paper 33, “Opp.”), and Patent Owner filed a Reply in support of its Motion (Paper 37). Patent Owner seeks to exclude Exhibit 1022, Exhibit 1025, certain paragraphs of the Exhibit 1026 (Second Tellado Decl.), and Exhibits 1023, 1024, and 1028 and testimony regarding the same. Mot. 2–12. As movant, Patent Owner has the burden of proof to establish that it is entitled to the requested relief. *See* 37 C.F.R. § 42.20(c). For the reasons stated below, Patent Owner’s Motion to Exclude is *dismissed*.

Exhibit 1022 is styled “Robert T. Short, ‘Physical Layer,’ *in* WIMEDIA UWB (2008),” and Exhibit 1025 is a copy of Dr. Tellado’s thesis. Reply 5. Patent Owner argues that we should exclude Exhibits 1022 and 1025 as irrelevant under Federal Rule of Evidence (“FRE”) 402. Motion 2–6. These exhibits were not cited or discussed in Petitioner’s Reply, and we did not rely on Exhibit 1022 or 1025, or Dr. Tellado’s statements with respect to Exhibits 1022 and 1025, in rendering our decision. We did not and need not consider Exhibits 1022 and 1025. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence or the portion of Dr. Tellado’s statements that discuss

Exhibits 1022 and 1025. Accordingly, we *dismiss* Patent Owner's Motion to Exclude as to these exhibits.

Exhibit 1023 is styled "Denis J. G. Mestdagh and Paul M. P. Spruyt, 'A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions on Communications*, Vol. 44, No. 10, (October 1996)." Reply 5. Exhibit 1024 is styled "Stefan H. Muller and Johannes B. Huber, 'A Comparison of Peak Power Reduction Schemes for OFDM,' IEEE Global Telecommunications Conference (1997)." *Id*. Exhibit 1028 is styled "T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected pages)." *Id*. Exhibit 2013 is a copy of the cross examination transcript of Dr. Tellado.

Patent Owner argues that we should exclude Exhibits 1023, 1024, and 1028 in their entirety as irrelevant. Motion 9–12. Patent Owner also argues that we should exclude certain portions of Exhibit 2013 allegedly discussing Exhibits 1023, 124, or 1028. *Id*. Although Exhibits 1023, 1024, and 1028 are mentioned briefly in Petitioner's Reply, we did not rely on Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013 in rendering our decision. We did not and need not consider Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Finally, Patent Owner argues that we should exclude paragraphs 16 (last two sentences), 29, 42, 43 (first sentence), and 52 of Exhibit 1026 (Second Tellado Declaration), and certain portions of Dr. Tellado's cross

examination transcript (Exhibit 2013) under FRE 702 as being based on insufficient facts or data due to an alleged undisclosed simulation. Motion 6–9. We did not rely on the objected to portions of Exhibits 1026 or 2013 in rendering our decision. We did not and need not consider the objected to portions of Exhibits 1026 or 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence. Accordingly, we *dismiss* Patent Owner's Motion to Exclude as to these paragraphs of Exhibit 1026 and these portions of Exhibit 2013.

For all of the above reasons, we *dismiss* Patent Owner's Motion to Exclude.

G. Motion for Observations

Patent Owner also filed a Motion for Observations (Paper 27, "Obs."), to which Petitioner filed a Response (Paper 34, "Obs. Resp."). To the extent Patent Owner's Motion for Observations pertains to testimony purportedly impacting Dr. Tellado's credibility, we have considered Patent Owner's observations and Petitioner's responses in rendering this Final Written Decision, and accorded Dr. Tellado's testimony appropriate weight in view of Patent Owner's observations and Petitioner's response to those observations. *See* Obs. 1–13; Obs. Resp. 2–11.

III. CONCLUSION

Petitioner has demonstrated, by a preponderance of the evidence, that (1) claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively and Stopler; and (2) claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and Gerszberg.

IV. ORDER

Accordingly, it is

ORDERED that claims 1–25 of the ’243 patent are determined to be *unpatentable*;

FURTHER ORDERED that Patent Owner’s Motion to Exclude is *dismissed*; and

FURTHER ORDERED that, because this is a Final Written Decision, parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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Paper 44
Entered: October 26, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and, MATTHEW R. CLEMENTS, *Administrative Patent Judges.*

MEDLEY, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

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[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

I. INTRODUCTION

In this *inter partes* review, instituted pursuant to 35 U.S.C. § 314, Cisco Systems, Inc. ("Petitioner") challenges claims 1–30 ("the challenged claims") of U.S. Patent No. 8,718,158 B2 (Ex. 1001, "the '158 patent"), owned by TQ Delta, LLC ("Patent Owner"). We have jurisdiction under 35 U.S.C. § 6. This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed below, Petitioner has shown by a preponderance of the evidence that the challenged claims are unpatentable. Patent Owner's Motion to Exclude is *dismissed*.

A. Procedural History

Petitioner filed a Petition for *inter partes* review of claims 1–30 of the '158 patent. Paper 2 ("Pet."). Patent Owner filed a Preliminary Response. Paper 6 ("Prelim. Resp."). On November 4, 2016, we instituted an *inter partes* review of claims 1–30 of the '158 patent on the following grounds (Paper 7 ("Dec.")):

References	Basis	Claims Challenged
Shively,[2] and Stopler[3]	§ 103(a)	1, 2, 4, 15, 16, and 18
Shively, Stopler, and Gerszberg[4]	§ 103(a)	3, 5, 14, 17, 19, and 28–30
Shively, Stopler, and Bremer[5]	§ 103(a)	6, 9, 10, 12, 20, 23, 24, and 26
Shively, Stopler,	§ 103(a)	8, 11, 13, 22, 25, and 27

[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) ("Shively").
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) ("Stopler").
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) ("Gerszberg").
[5] U.S. Patent No. 4,924,516; issued May 8, 1990 (Ex. 1017) ("Bremer").

References	Basis	Claims Challenged
Bremer, and Gerszberg		
Shively, Stopler, Bremer, and Flammer[6]	§ 103(a)	7 and 21

Thereafter, Patent Owner filed a Patent Owner Response ("PO Resp."). Paper 15. Petitioner filed a Reply to the Patent Owner Response ("Pet. Reply"). Paper 20. Pursuant to an Order (Paper 24), Patent Owner filed a listing of alleged statements and evidence in connection with Petitioner's Reply deemed to be beyond the proper scope of a reply. Paper 25. Petitioner filed a response to Patent Owner's listing. Paper 32.

Patent Owner filed a Motion to Exclude, Paper 31 ("PO Mot. Exc."), Petitioner filed an Opposition, Paper 36 ("Pet. Opp. Mot. Exc."), and Patent Owner filed a Reply, Paper 40. Patent Owner filed a Motion for Observation, Paper 30 ("PO Mot. Obs.") and Petitioner filed a Response to the Motion for Observation, Paper 37 ("Pet. Resp.").

We held a consolidated hearing on August 3, 2017, for this case and related Case IPR2016-01020, and a transcript of the hearing is included in the record. Paper 42 ("Tr.").

B. Related Proceedings

The parties indicate that the '158 patent is the subject of several pending judicial matters. Pet. 1; Paper 5, 2–3.

C. The '158 Patent (Ex. 1001)

The '158 patent relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

[6] U.S. Patent No. 5,515,369; issued May 7, 1996 (Ex. 1019) ("Flammer").

Ex. 1001, 1:28–31. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:38–41. The value is determined independent of the input bit value carried by the carrier signal. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals. *Id.* at 2:38–45. Figure 1 illustrates the multicarrier communication system and is reproduced below:

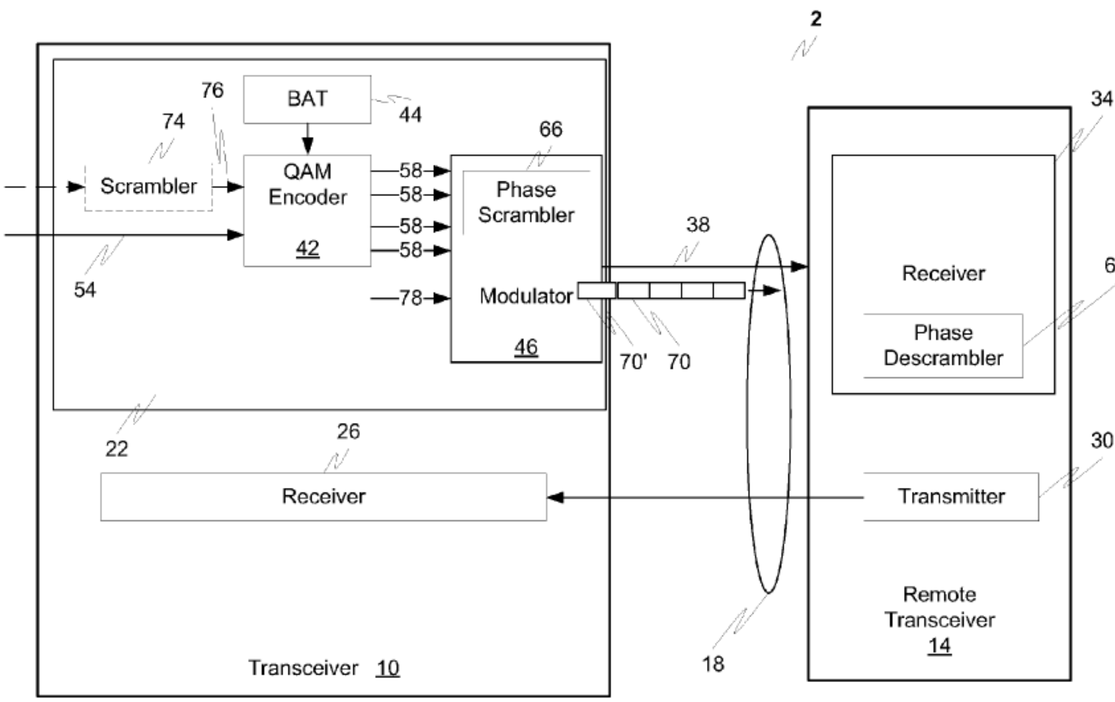

FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2, which includes discrete multitoned (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:27–31. DMT transceiver 10 includes

DMT transmitter 22 and DMT receiver 26. *Id.* at 3:31–32. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:32–34. DMT transmitter 22 transmits signals over communication channel 18 to receiver 34. *Id.* at 3:40–42.

DMT transmitter 22 includes a quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase scrambler 66. *Id.* at 3:53–56. QAM encoder 42 has a single input for receiving serial data bit stream 54 and multiple parallel outputs to transmit QAM symbols 58 generated by QAM encoder 42 from bit stream 54. *Id.* at 3:65–4:1. Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:12–14. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:15–18. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:31–34.

D. Illustrative Claim

Petitioner challenges claims 1–30 of the ’158 patent. Claims 1 and 15 are independent claims. Claims 2–14 and 29 depend, either directly or indirectly, from claim 1, and claims 16–28 and 30 depend, either directly or indirectly, from claim 15. Claim 1 is reproduced below.

> 1. In a multicarrier modulation system including a first transceiver in communication with a second transceiver using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits, each carrier signal having a phase characteristic associated with at least one bit of the

> plurality of data bits, a method for scrambling the phase characteristics of the carrier signals comprising:
>
> transmitting the plurality of data bits from the first transceiver to the second transceiver;
>
> associating a carrier signal with a value determined independent of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator;
>
> determining a phase shift for the carrier signal at least based on the value associated with the carrier signal;
>
> modulating at least one bit of the plurality of data bits on the carrier signal; and
>
> modulating the at least one bit on a second carrier signal of the plurality of carrier signals.

Ex. 1001, 10:59–11:11.

II. ANALYSIS

A. Principles of Law

To prevail in its challenge to Patent Owner's claims, Petitioner must demonstrate by a preponderance of the evidence that the claims are unpatentable. 35 U.S.C. § 316(e); 37 C.F.R. § 42.1(d). A claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR Int'l Co. v. Teleflex, Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the

prior art; (3) the level of ordinary skill in the art; and (4) objective evidence of nonobviousness. *Graham v. John Deere Co. of Kansas City*, 383 U.S. 1, 17–18 (1966).

In that regard, an obviousness analysis "need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ." *KSR*, 550 U.S. at 418; *see also Translogic Technology, Inc.*, 504 F.3d 1249, 1259, and 1262 (Fed. Cir. 2007).

B. Level of Ordinary skill in the Art

Citing its declarant, Dr. Jose Tellado, Petitioner contends that a person having ordinary skill in the art at the time of the invention would have had (1) a Master's degree in Electrical and/or Computer Engineering, or equivalent training, and (2) approximately five years of experience working with multicarrier communications systems. Pet. 10–11; Ex. 1009 ¶ 18. Petitioner also contends that "[l]ack of work experience can be remedied by additional education, and vice versa." Pet. 11.

Patent Owner's expert, Dr. Robert Short indicated that for purposes of the proceeding he adopts Dr. Tellado's definition of a person of ordinary skill in the art. Ex. 2003 ¶ 16. For purposes of this Decision, we adopt Petitioner's proposed definition, and further find that the level of ordinary skill in the art is reflected by the prior art of record. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001); *In re GPAC Inc.*, 57 F.3d 1573, 1579 (Fed. Cir. 1995); *In re Oelrich*, 579 F.2d 86, 91 (CCPA 1978).

C. Claim Interpretation

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); *see also* Office Patent Trial Practice Guide, 77 Fed. Reg. at 48,766. Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic*, 504 F.3d at 1257.

Petitioner proposes constructions for the following claim terms: "multicarrier" and "transceiver." Pet. 8–9. In our Decision to Institute, we interpreted the term "transceiver" to mean "a device, such as a modem, with a transmitter and receiver," but determined that it was not necessary to interpret the term "multicarrier." Dec. 6–7. Neither party has indicated that our determinations were improper and we do not perceive any reason or evidence that now compels any deviation from our initial determinations. PO Resp. 13–14; Pet. Reply 7–8. Accordingly, the construction of transceiver to mean "a device, such as a modem, with a transmitter and receiver" applies to this Decision. Dec. 7. For purposes of this decision, we find it necessary to construe "scrambling the phase characteristics of the carrier signals" found in claim 1.

Scrambling the Phase Characteristics of the Carrier Signals

The preamble of claim 1 recites a transmission signal with a plurality of carrier signals where each carrier signal has a phase characteristic and "a method for *scrambling the phase characteristics of the carrier signals*, comprising." (Emphasis added). Patent Owner argues that the italicized language should be interpreted to mean "adjusting the phases of a plurality

of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14–19. Petitioner argues that the phrase needs no interpretation, since the prior art relied upon uses the same "phase scrambling" terminology to describe pseudo-random phase changes. Pet. Reply 7 (citing Ex. 1012, 12:24–31). Additionally, Petitioner argues, without any other explanation, that "the Board should not adopt TQ Delta's proposed construction." *Id*. During oral argument, however, counsel for Petitioner reiterated that it is Petitioner's position that no construction of the term is necessary, because "[r]egarding [P]atent [O]wner's proposal of the construction, we believe that is exactly how Stopler is describing this phase scrambler as operating." Tr. 18:23–19:5.

The phrase "scrambling the phase characteristics of the carrier signals" is recited in the preamble of claim 1. Although neither party explicitly explains why the preamble of claim 1 is limiting, both parties implicitly contend that the preamble is limiting. For purposes of this decision, we determine that the preamble is limiting. We further find it helpful to our decision and analysis to interpret the phrase in order to understand the parties' positions with respect to how the prior art reference Stopler meets the phrase.

Patent Owner argues that "scrambling the phase characteristics of the carrier signals" should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14. Patent Owner contends that the construction is supported by the specification of the '158 patent and clarifies that the claimed phase scrambling "must be performed amongst the individual carrier phases in a single multicarrier symbol" and is not met if

the phase adjustment only occurs over time from one symbol to the next. PO Resp. 14 (citing Ex. 2003 ¶ 37).

In support of its proposed interpretation, Patent Owner argues that the ’158 patent describes that each of the plurality of carriers (of a multicarrier signal) corresponds to a different QAM symbol. PO Resp. 15 (citing Ex. 1001, 4:15–16). Patent Owner further argues that each carrier (or QAM symbol) has its own phase or phase characteristic, and that the combination of the carriers (or QAM symbols) is referred to as a DMT symbol. PO Resp. 16 (citing Ex. 1001, 4:9–11, 9:8–9; Ex. 2003 ¶ 39). Patent Owner further contends that the ’158 patent describes that a “phase scrambler” scrambles phases or phase characteristics of carriers within a single DMT symbol, and that PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. PO Resp. 16 (citing Ex. 1001, 6:32–8:13; Ex. 2003 ¶ 39). PAR, Patent Owner contends, would not be reduced if carrier phases were only adjusted from one symbol to the next. PO Resp. 16 (Ex. 2003 ¶¶ 41–42).

Based on the record before us, we agree with Patent Owner’s proposed construction as far as meaning “adjusting the phases of a plurality of carriers in a single multicarrier symbol.” PO Resp. 14. Patent Owner, however, provides no persuasive reasoning for also adding to that construction “by pseudo-randomly varying amounts.” *Id.* Rather, Patent Owner merely contends that (1) in a corresponding district court matter, the court construed the phrase to mean “adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts;” (2) during prosecution of a child application to the ’158 patent, the applicant explained that a “scrambler” operates by pseudo-randomly selecting bits to invert; and

(3) there was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristic of a carrier signal by pseudo-randomly varying amounts. PO Resp. 16–17. Patent Owner's explanation for why we should add "by pseudo-randomly varying amounts" to its proposed construction is conclusory. *Id.* at 17. We interpret claims using the broadest reasonable construction in light of the specification of the involved patent. That standard is not the same as the standard used in district court. Patent Owner, however, provides no explanation for why we should apply the district court construction, which is not necessarily the same as used before us, here. Moreover, Patent Owner does not explain why statements made during prosecution of a child application for the term "scrambler" is relevant to how we should interpret the disputed phrase that does not even contain the term "scrambler" in it. *Id.* at 16. In summary, Patent Owner's arguments are conclusory.

For all of the above reasons, and for purposes of this decision, we determine that "scrambling the phase characteristics of the carrier signals" means "adjusting the phases of a plurality of carriers in a single multicarrier symbol."

D. Asserted Obviousness over Shively and Stopler

Petitioner contends that claims 1, 2, 4, 15, 16, and 18 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 11–32. We have reviewed Petitioner's showing identifying where each limitation allegedly appears in Shively and Stopler, along with the testimony of Petitioner's declarant, Dr. Jose Tellado. *Id*. (citing Ex. 1009). We also have reviewed Patent Owner's assertions and evidence, including the testimony of Dr. Robert Short, as to why Petitioner's showing is deficient.. PO Resp.

Shively (Ex. 1011)

Shively discloses discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitoned modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.* at 10:29–30. The serial stream is segmented in to N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator

generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

Stopler (Ex. 1012)

Stopler discloses a method and apparatus for encoding/framing a data stream of multitoned modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67. A code having lower redundancy can be used since the amount of corruption expected in one user's data packet will be reduced. *Id.* at 5:67–6:3.

Figure 5 of Stopler is reproduced below.

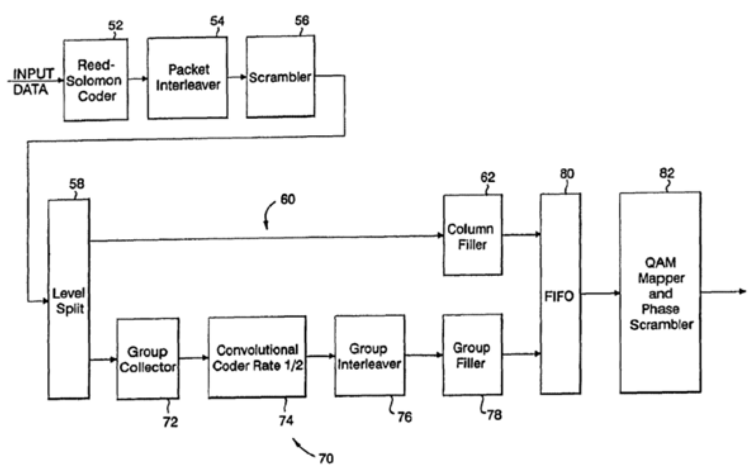

FIG. 5

As shown above, Figure 5 of Stopler, input data, in the form of data packets, is input to an RS coder 52. *Id.* at 8:55–57. Data output by RS coder 52 is input to interleaver 54. *Id.* at 9:8–10. The output of interleaver 54 is rearranged into a serial bit stream and then scrambled in scrambler 56, which is used to randomize coded and interleaved data. *Id.* at 9:34–37. Data output by scrambler 56 is divided by level splitter 58 into two levels of the TCM encoder. Splitter 58 divides serial bit stream into a group of data bits to be processed by lower level 70, and the remaining data bits to be processed by upper level 60. *Id.* at 9:48–55. In lower level 70 of TCM encode, data is collected into groups by group collector 72, which is input to coder 74, then group interleaver 76 and then group filler 78. *Id.* at 10:40–11:18. The outputs of upper stream 60 and lower stream 70 are combined into m-tuples (QAM symbols) and temporarily stored in FIFO buffer 80, which then delivers data to a QAM mapper 82. *Id.* at 11:51–57.

The input to QAM mapper 82 is data in the form of m-tuples which are mapped into QAM symbols. *Id.* at 12:21–22. To randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols. For example, the phase scrambling sequence may be generated by a pseudo-random generator composed of a linear feedback shift register of length 21, and initialized by a user programmable seed. *Id.* at 12:24–31. Consecutive output pairs from the pseudo-random generator are converted into numbers 2a+b and the sum (2a+b) is used to select the amount of rotation to be applied to the symbol according to the following table below:

2a + b		Phase Rotation
0	→	0
1	→	$+\pi/2$
2	→	π
3	→	$-\pi/2$

Id. at 12:31–45. The output from the QAM mapper 82 is provided to a modulator (not shown) which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc. *Id.* at 12:55–57.

Analysis

Petitioner contends that claims 1, 2, 4, 15, 16, and 18 would have been obvious over Shively and Stopler. Pet. 11–32. Patent Owner's arguments are directed to whether a person of ordinary skill in the art would have combined Shively and Stopler and whether Stopler describes phase scrambling. PO Resp. 45–58.

Claim 1 recites "[i]n a multicarrier modulation system including a first transceiver in communication with a second transceiver." Petitioner contends that Shively and Stopler each describe this limitation. For example, and with respect to Shively, Petitioner argues that Shively describes a discrete multitoned transmission (DMT) of data (a multicarrier modulation system) by digital subscriber loop (DSL) modems (illustrated in Figure 2 as a transmitting modem 31 and a receiving mode 32). Pet. 17 (citing Ex. 1011, 1:5–7, 9:42, 9:63–64, and Fig. 2; Ex. 1009, 31–32).[7] We are persuaded by Petitioner's showing and find that Shively's modem 31 is a first transceiver in communication with a second transceiver 32 and that the

[7] In the Petition, Petitioner references page numbers of Dr. Tellado's Declaration, as opposed to paragraph numbers. Citations are to page numbers, unless otherwise indicated by use of the paragraph symbol ("¶").

two transceivers communicate using discrete multitoned transmission (DMT) of data, and thus are in a multicarrier modulation system.

Claim 1 further recites "using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits." Petitioner contends that Shively and Stopler each render obvious this phrase. For example, and with respect to Shively, Petitioner contends that Shively describes a transmitting modem that receives digital data from a data source and modulates separate carriers to represent the digital data, which results in a modulated signal sent to a receiving modem. Pet. 19 (citing Ex. 1011, 5:22–26). Petitioner further contends that Shively describes that the available frequency spectrum is divided into multiple QAM channels, which a person of ordinary skill in the art would have understood to be a "plurality of carrier signals" for modulating "a plurality of data bits." Pet. 19 (citing Ex. 1011, 5:47, 5:52; Ex. 1009, 35–36). We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Shively renders obvious "using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits."

Claim 1 recites "each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits." Petitioner contends that Shively and Stopler each render obvious this phrase. For example, and with respect to Shively, Petitioner contends that Shively describes transmitting data bits using quadrature amplitude modulation (QAM) and that QAM produces a signal whose phase and amplitude convey encoded k-bits of information. Pet. 20 (citing Ex. 1011, 1:29–30). Petitioner further contends that a person having ordinary skill in the art would have understood that the phase of a signal used in QAM to convey

bits is a phase characteristic as claimed. Pet. 20 (citing Ex. 1001, 1:43–44; Ex. 1009, 38). We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Shively describes "each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits."

Claim 1 further recites a "method for scrambling the phase characteristics of the carrier signals." Petitioner contends that Stopler describes a phase scrambler that applies a phase scrambling sequence to data in the form of m-tuples which are to be mapped into QAM symbols. Pet. 22 (citing Ex. 1012, 12:20–28). Petitioner contends that the QAM symbols are then provided to a modulator which implements the particular signal modulation. Pet. 22; Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 41–45).

Petitioner explains, with supporting evidence, that it would have been understood by a person having ordinary skill in the art that modulating the phase-scrambled QAM symbols results in the phases of the carrier signals being scrambled. Pet. 22 (citing Ex. 1009, 44–45). Petitioner contends that it would have been obvious to a person having ordinary skill in the art to employ Stopler's phase scrambling techniques in Shively's transmitter. Pet. 22–23 (citing Ex. 1009, 45). In particular, Dr. Tellado testifies that a person having ordinary skill in the art would have recognized that by transmitting redundant data symbols on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio (PAR). Ex. 1009 ¶¶ 63–64. He further testifies that a person having ordinary skill in the art would have understood the drawbacks from a high PAR and that such a person would have sought out an approach to reduce PAR of Shively's transmitter. *Id.* ¶ 66. Dr. Tellado further testifies that it would have been

obvious to randomize the carrier phases using Stopler's techniques in order to reduce Shively's PAR. *Id.* ¶ 67. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that Stopler teaches "scrambling the phase characteristics of the carrier signals" and that it would have been obvious to combine Stopler's scrambling technique to Shively's system for the reasons provided by Petitioner. Pet. 23.

Claim 1 also recites "transmitting the plurality of data bits from the first transceiver to the second transceiver." As discussed above, Petitioner relies on Shively's description of a transmitting modem (e.g., Figure 2 transmitting modem 31) that transmits digital data to a receiving modem (e.g., Figure 2 receiving modem 32). Pet. 23 (citing Ex. 1011, 8:56–60). We find that Shively describes transmitting digital data from a first transceiver to a second transceiver. Ex. 1011, 8:56–60. Petitioner further explains, with supporting evidence, and we agree, that a person having ordinary skill in the art would have understood that Shively's digital data are "data bits." Pet. 23 (citing Ex. 1009, 46); *see also* Ex. 1011, 5:47–58.

Claim 1 also recites "associating a carrier signal with a value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator." Petitioner relies on Stopler to meet this limitation. In particular, Petitioner contends that Stopler teaches a pseudo-random generator that outputs consecutive output pairs that are converted into numbers 2a+b. Pet. 24 (citing Ex. 1012, 12:28–45). The value (2a+b), derived from the pseudo-random number generator, Petitioner

contends, is a "value determined independently of any bit of the plurality of data bits carried by the carrier signal." Pet. 24 (citing Ex. 1009, 48). Petitioner further explains, with supporting evidence, that because Stopler teaches that the value (2a+b) is associated with a symbol that is transmitted on a sub-channel having a carrier frequency, the value (2a+b) is associated with a carrier signal. Pet 24–25 (citing Ex. 1009, 48–49). We are persuaded by Petitioner's showing, which we adopt, that Stopler renders obvious associating a carrier signal with a "value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator."

Claim 1 recites "determining a phase shift for the carrier signal at least based on the value associated with the carrier signal." Petitioner contends that Stopler teaches that the (2a+b) value is used to determine a phase shift because the sum (2a+b) is used to select the amount of rotation to be applied to the symbol, where the phase rotation can be 0, $\pi/2$, π, or $-\pi/2$. Pet. 25 (citing Ex. 1012, 12:28–45; Ex. 1009, 49). Petitioner contends that a person having ordinary skill in the art would have understood that applying a rotation to the symbol results in a phase shift in the carrier signal after the symbol is modulated onto the carrier. Pet. 25–26 (citing Ex. 1009, 49). We are persuaded by Petitioner's showing, which we adopt, that Stopler renders obvious "determining a phase shift for the carrier signal at least based on the value associated with the carrier signal."

Claim 1 recites "modulating at least one bit of the plurality of data bits on the carrier signal" and "modulating the at least one bit on a second carrier signal of the plurality of carrier signals." Petitioner points to descriptions in

Shively that describes determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream." Pet. 26 (quoting Ex. 1011, 8:3–6, 8:5–13). Petitioner further contends that Shively employs QAM multitone modulation to modulate carriers, and Shively's multiple sub-bands or QAM channels correspond to the claimed "plurality of carrier signals." Pet. 26 (citing Ex. 1009, 51). Petitioner submits that Stopler also teaches using QAM to convey data bits on carrier signals. Pet. 26–27. Petitioner further argues that Shively discloses modulating a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 27–29. We are persuaded by Petitioner's showing, which we adopt, that the combined teachings of Shively and Stopler render obvious "modulating at least one bit of the plurality of data bits on the carrier signal" and "modulating the at least one bit on a second carrier signal of the plurality of carrier signals."

Independent claim 15 is similar to claim 1. Petitioner has made a showing with respect to claim 15 similar to its showing with respect to claim 1. *See, e.g.*, Pet. 30–32. To the extent that claim 15 is different from claim 1, Petitioner has accounted for such differences. We also have reviewed Petitioner's showing with respect to dependent claims 2, 4, 16, and 18. Claim 2 depends from claim 1 and recites "wherein one or more of the first transceiver and second transceiver are cable transceivers." Claim 16, which depends from claim 15 is similar. Petitioner sufficiently accounts for this limitation by explaining that Stopler describes a cable modem attached to a cable television network and is a "cable transceiver." Pet. 29 (citing Ex.

1012, 1:28–33, 2:9–22, and 12:55–57; Ex. 1009, 55–56). We find that Stopler describes a cable modem that meets the limitation of a cable transceiver. Petitioner contends, and we agree, that it would have been obvious to a person having ordinary skill in the art that the data transmission techniques of Shively and Stopler could be employed with a cable transceiver. Pet. 29 (citing Ex. 1009, 56).

Claim 4 depends from claim 1 and "wherein the first and second transceivers are multicarrier DSL transceivers." Claim 18, which depends from claim 15 is similar. Petitioner sufficiently accounts for this limitation by explaining, for example, that Shively describes discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems. Pet. 30 (citing Ex. 1011, 1:5–8). Patent Owner does not make any additional arguments regarding claims 2, 4, 15, 16, and 18 that do not pertain to claim 1. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 1, 2, 4, 15, 16, and 18 are unpatentable as obvious over Shively and Stopler.

Patent Owner's Contentions

Patent Owner argues that the combined teachings of Shively and Stopler do not render obvious the challenged claims. PO Resp. 44. In particular, Patent Owner argues that (1) Petitioner provides no explanation for the "use of a known technique to improve a similar device" rationale to combine Shively and Stopler (*id*. at 45–47); (2) Petitioner wrongly claims that Shively's transmitter suffers from an increased PAR (*id*. at 47–49); (3) Petitioner's combination of Shively and Stopler suffers from hindsight (*id*. at 49–50); (4) there is no need to solve Shively's non-existent PAR problem

(*id*. at 50–51); (5) Stopler does not reduce PAR in a multicarrier transmitter (*id*. at 51); (6) Stopler and Shively could not be combined (*id*. at 51–55); and (7) there were no "market forces" in effect to prompt the Shively/Stopler combination (*id*. at 55–57). Patent Owner also argues that Stopler does not disclose phase scrambling. *Id*. at 57–59. We address each argument below.[8]

Scrambling the Phase Characteristics of the Carrier Signals

Patent Owner argues that Stopler does not disclose "scrambling the phase characteristics of the carrier signals" required by claim 1. PO Resp. 34–44, 57–58. We note, independent claim 15 does not recite this phrase. In essence, Patent Owner argues that claim 1 requires adjusting the phases of a plurality of carriers in a single multicarrier symbol, but that Stopler only discloses scrambling phases from one symbol to the next symbol and not with respect to multiple carriers in a single multicarrier symbol. *Id*.

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[8] Patent Owner lists several portions of Petitioner's Reply and evidence allegedly beyond the scope of what can be considered appropriate for a reply. *See* Paper 25. We have considered Patent Owner's listing, but disagree that the cited portions of Petitioner's Reply and reply evidence are beyond the scope of what is appropriate for a reply. Replies are a vehicle for responding to arguments raised in a corresponding patent owner response. Petitioner's arguments and evidence that Patent Owner objects to (Paper 25, 1–2) are not beyond the proper scope of a reply because we find that they fairly respond to Patent Owner's arguments raised in Patent Owner's Response. *See Idemitsu Kosan Co. v. SFC Co. Ltd.*, 870 F.3d 1376, 1381 (Fed. Cir. 2017) ("This back-and-forth shows that what Idemitsu characterizes as an argument raised 'too late' is simply the by-product of one party necessarily getting the last word. If anything, Idemitsu is the party that first raised this issue, by arguing—at least implicitly—that Arkane teaches away from non-energy-gap combinations. SFC simply countered, as it was entitled to do.").

In particular, Patent Owner contends that "Stopler must be compatible with single-carrier CDMA" (PO Resp. 58) based on Stopler's teaching that "[t]he framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System." Ex. 1012, 12:58–63; *see also* PO Resp. 29–30; *id.* at 29–44 (arguing Stopler's framing scheme must be compatible with single-carrier CDMA). According to Patent Owner, "[b]ecause Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol." PO Resp. 58. Thus, concludes Patent Owner, "Stopler only discloses scrambling phases from one symbol[9] to the next symbol in time, and not with respect to multiple carriers in a single multicarrier symbol." PO Resp. 58; *see also id.* at 37 ("It is nonsensical to scramble phases within a symbol because there is only one phase in each symbol.").

Patent Owner also relies on Stopler's claim 31 as corroboration for its position, contending that the phase scrambling performed by QAM Mapper and Phase Scrambler 82 "must at least be compatible with single carrier CDMA" because claim 31 is directed to a method in a "CDMA system" that includes the step of "phase scrambling." *Id*. at 33–34 (citing Ex. 1012, 16:4–48).

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[9] Patent Owner uses "symbol" to mean "a collective multicarrier symbol in a single symbol period (*e.g*. a DMT symbol)." PO Resp. 12. Patent Owner uses "carrier" to mean "a carrier symbol (*e.g*., a QAM symbol)." *Id*.

The "framing scheme" of Stopler is shown as a block diagram in Figure 5, reproduced below. Ex. 1012, 8:54–55 ("A block diagram of the framing scheme according to the present invention is shown in FIG. 5.").

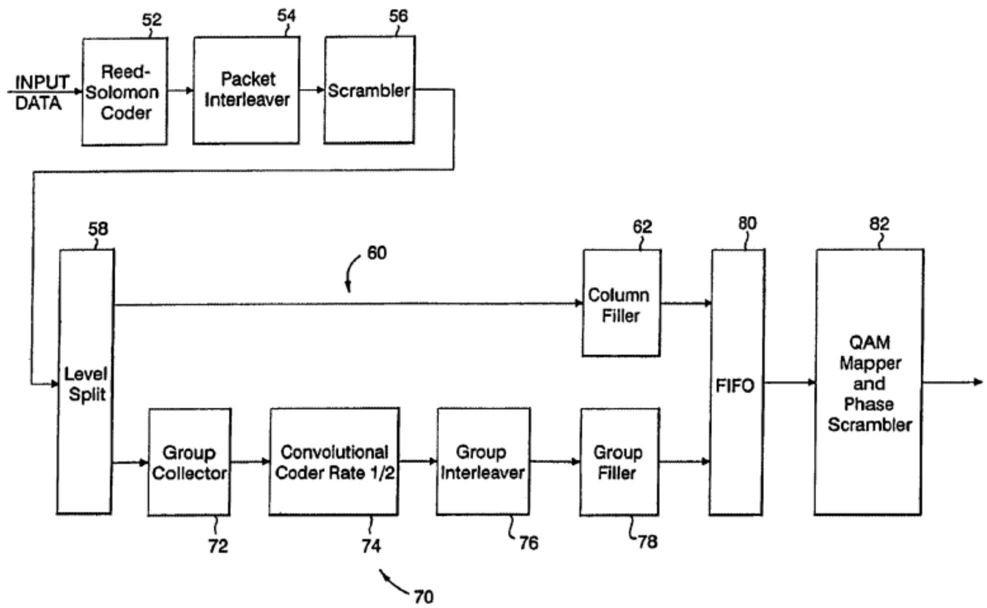
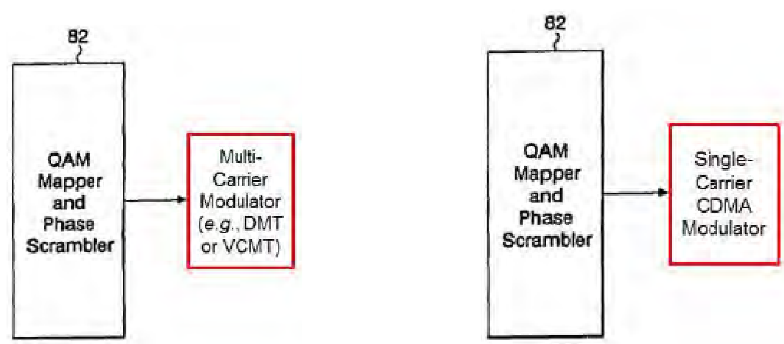


FIG. 5

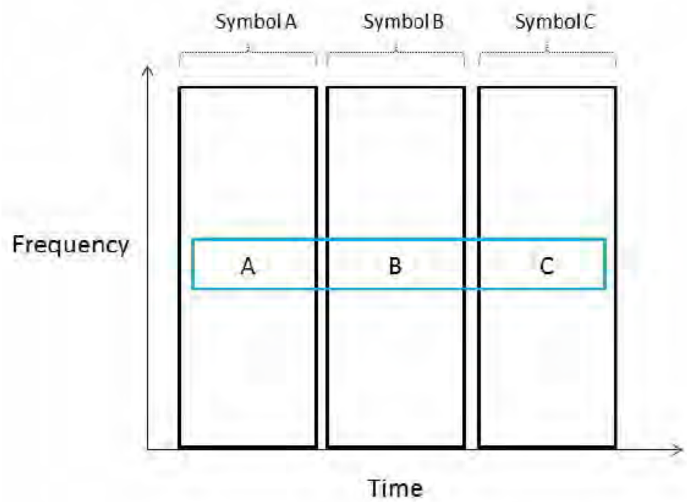
To illustrate the use of Stopler's framing scheme with either a multicarrier modulator or a single carrier modulator, Patent Owner provides the following annotated excerpts of Figure 5:



PO Resp. 33.

We are not persuaded by Patent Owner's argument, which is based upon its assertion that "[s]ingle-carrier systems have only one carrier with only one phase" and, therefore, "[p]hase scrambling in a single-carrier

system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box," in the figure reproduced below. PO Resp. 36–37.



Id. In this diagram, "Symbol A," "Symbol B," and "Symbol C" each represent a QAM symbol, not a DMT symbol, and each, according to Patent Owner, is phase scrambled relative to the other. Thus, Patent Owner's diagram shows only that a single-carrier embodiment of Stopler would transmit one phase-scrambled QAM symbol at a time. It does *not* show that QAM Mapper and Phase Scrambler 82 phase scrambles a DMT symbol—i.e., rotates, by the same amount, the phase of a plurality of QAM symbols. This is consistent with the cross-examination testimony of Patent Owner's expert, Dr. Short, who admitted that Stopler does not describe phase scrambling DMT symbols. Pet. Reply 17–18 (citing Ex. 1027, 60:11–14). Thus, Patent Owner's own diagram is consistent with Petitioner's position that Stopler phase scrambles individual QAM symbols, and Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not

supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol.

Whereas Patent Owner's position relies upon inference, Petitioner's position is supported by express disclosure in Stopler, which unambiguously teaches "QAM symbols, for example,[] 256-QAM" whose "constellation mapping may be the same as that used in ADSL." Ex. 1012, 12:20–24. Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id.* at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Pet. Reply 16–17 (citing Ex. 1027, 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, and 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudo-random generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a *single* QAM symbol by that amount. Patent Owner, in contrast, identifies nothing in Stopler to suggest that QAM Mapper and Phase Scrambler 82 rotates the phase of a *plurality* of QAM symbols (e.g., every QAM symbol of a DMT symbol) by the same amount. Finally, we agree with Petitioner's argument that because "a CDMA modulator does not employ DMT symbols, there is no reason for Stopler's phase scrambler to operate on DMT symbols," whereas "both DMT and CDMA modulators employ QAM symbols," so "applying the phase scrambler to individual QAM symbols[] is the only

possible reading that is logically and technically coherent." Pet. Reply 18 (citing Ex. 1026 ¶ 58).

Patent Owner also argues that a person of ordinary skill in the art would have understood Stopler to be scrambling phase from symbol-to-symbol over time in order to reduce narrowband noise at the frequency of an overhead pilot carrier. PO Resp. 39; *see also id.* at 38–44 (citing Ex. 2004 (U.S. Patent 6,370,156, "the '156 patent")). According to Patent Owner, "Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones." *Id.* at 40. We understand Patent Owner to be alluding to pages 13 to 14 of the Petition, which state

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26.

Pet. 13. In the claim-by-claim analysis of the Petition, however, Petitioner cites lines 20 to 28 of column 12, which include Stopler's teaching that "the phase scrambler is applied to all symbols, not just the overhead symbols." *See* Pet. 22 (quoting Ex. 1012, 12:27–28). Thus, Petitioner is relying not just on the scrambling of "overhead signals, such as pilot tones," (Pet. 13) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive.

Finally, we are not persuaded by Patent Owner's argument that only its interpretation—i.e., adjusting the phase of an entire DMT symbol—would "simplify implementation," as Stopler teaches (Ex. 1012, 12:26),

whereas Petitioner's interpretation would add complexity. PO Resp. 44 (citing Ex. 2003 ¶ 90). Patent Owner provides no explanation or analysis to support its conclusory assertions regarding simplicity and complexity, and the cited portion of Dr. Short's declaration merely repeats what is written in the Patent Owner's Response.

For the foregoing reasons, we are persuaded that Stopler teaches "scrambling the phase characteristics of the carrier signals" required by claim 1.

No Use of a Known Technique to Improve a Similar Device Rationale

Patent Owner argues that in making the contention that the combination of Shively and Stopler is a use of a known technique to improve a similar device, method or product in the same way, Petitioner fails to explain what is the known technique, what device/method/product is similar, and how is the alleged known technique used for improvement in the same way. PO Resp. 45–47.

In the Petition, Petitioner provides sufficient explanation regarding the reasons to combine Shively and Stopler. Pet. 14–16. The explanation provided in the Petition is not conclusory or confusing as Patent Owner asserts. The known technique is identified as phase scrambling. Pet. 15 (citing Ex. 1009, 29). The similar device is Shively's modem. Pet. 17. And the improvement to it is the same as in Stopler—to reduce PAR. Pet. 16 (citing Ex. 1009, 29).

Shively's transmitter does not suffer from an increased PAR and there is no reason to solve Shively's non-existent PAR problem

Patent Owner argues that "Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather,

Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic)." PO Resp. 47–49. Patent Owner also argues that because Shively does not disclose a problem with PAR, one having ordinary skill in the art would have had no reason to look for a solution. PO Resp. 50–51. We are not persuaded by these arguments.

Specifically, Patent Owner argues Shively's system is unlikely to suffer from clipping,[10] based on its analysis of a hypothetical 18,000 foot wire. PO Resp. 19–29. According to Patent Owner, the power of signals transmitted in Shively's proposed system would be "only 40% of maximum" in the normal mode for ADSL-1995 and "only 49% of maximum" in the power-boost mode of ADSL-1995. *Id.* Based on these figures, Patent Owner concludes that "the clipping probability for both normal and power-boost modes is virtually zero" because "[w]hile Shively's 'spreading' technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half." *Id.* at 28.

Petitioner argues that Dr. Short's analysis is flawed because (1) the teachings of Shively are not applicable only to 18,000 foot cables; and (2) Dr. Short "grossly underestimates the likelihood of phase alignment" in Shively because he wrongly assumes a Gaussian distribution. Pet. Reply 26–31. According to Petitioner, a proper analysis shows that Shively's

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[10] Patent Owner explains that, "[w]hen the maximum dynamic range of a component is exceeded, the signal will become distorted or will 'clip.'" PO Resp. 8. This is consistent with how the '158 patent uses "clipping." *See, e.g.,* Ex. 1001, 8:27–35.

techniques "significantly increases PAR and the likelihood of clipping." Pet. Reply 31–35.

We need not determine the exact probability of clipping in Shively's proposed system because, even assuming Patent Owner's analysis is accurate, it does not rebut Petitioner's reason to combine. Petitioner does not allege that Shively's proposed system causes clipping, or that a person of ordinary skill in the art would have been motivated to reduce PAR only if it caused clipping. Instead, Petitioner alleges that Shively's proposed system would have an "increased" or "high" PAR:

> A POSITA would have recognized that by transmitting redundant data on multiple carriers, *Shively's transmitter would suffer from an increased peak-to-average power ratio*. [Ex. 1009, p. 27.] This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. *Id*. When *N* subcarrier signals with the same phase are added together, they have a peak power which is *N* times greater than their individual maximum powers. *Id*.
>
> Since Shively's subcarriers use quadrature amplitude modulation (QAM) . . . transmitting the same bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. *Id*., pp. 27–28. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. *Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time*. *Id*., p. 28.

Pet. 14–15 (emphases added).

Patent Owner criticizes Petitioner's declarant for not providing "calculations or data that illustrate to what degree there is an 'increase' in PAR with Shively's transmitter" (PO Resp. 48), but we are not persuaded

that such calculations and data are necessary. Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold. There is no dispute that transmitting the same data on multiple carriers increases PAR (Pet. Reply 10 (citing PO Resp. 6–7; Ex. 2003 (Short Decl.) ¶ 22)) or that Shively's technique, specifically, will increase PAR (PO Resp. 28 ("Shively's 'spreading' technique will contribute a small uptick in clipping probability."). There also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR. Pet. Reply 36 (citing Ex. 2003 ¶ 26; Ex. 1027 45:21–46:19). Patent Owner's declarant, Dr. Short, testified that, given such issues, system designers or engineers would be interested in using techniques that could reduce PAR. Ex. 1027, 46:23–47:3. This is consistent with the reason to combine given in the Petition and supports Petitioner's position that "numerous problems" other than clipping "would have motivated a [person of ordinary skill in the art] to look for ways to reduce the PAR of Shively's technique." Pet. Reply 36.

In light of the foregoing, we are persuaded that a person of ordinary skill in the art would have recognized that Shively's technique would increase PAR and would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping.

Combination of Shively and Stopler suffers from hindsight

Patent Owner argues that only the inventor of the '158 patent recognized the problem of high PAR due to phase-aligned carriers. PO Resp. 49–50. Patent Owner argues that the only cited evidence that high PAR results from transmitting the same data on multiple carriers is from the '158 patent and that Petitioner "use[s] the '158 patent as a roadmap for

arriving at their theory of obviousness," resulting in "a textbook case of impermissible hindsight bias." *Id*. We are not persuaded by this argument.

First, the portions cited in the '158 patent in the Petition and in Dr. Tellado's declaration come from the "BACKGROUND OF THE INVENTION" section of the patent. That portion of the '158 patent uses words such as "conventional" indicating that what is described in the "BACKGROUND OF THE INVENTION" section is information that was known at the time of the invention, not just by the inventors, but persons of ordinary skill in the art. Patent Owner does not contend otherwise.

In addition, Dr. Tellado testified that a person having ordinary skill in the art would have recognized that the purpose of Stopler's phase scrambler to randomize data symbols would be to reduce PAR of transmitted signals and that the person would have been familiar with the problems created by a high PAR, including PAR due to phase-aligned carriers. Ex. 1009 ¶¶ 60, 66. Moreover, Patent Owner's own declarant recognized that PAR was a known problem at the time of the invention. Ex. 2003 ¶ 23 ("Conventional multicarrier systems, therefore, were designed to accommodate PAR."). The ANSI T1.413-1995 standard also confirms that PAR was known at the time of the invention by describing that "[a] DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analog converter." Ex. 1018, 36 (Section 6.5 "Tone ordering"). Based on the record evidence, we find that a person having ordinary skill in the art would have known about the problem of high PAR due to phase-aligned carriers.

Stopler does not reduce PAR in a multicarrier transmitter

Patent Owner argues that Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-carrier. PO Resp. 51. The argument is not persuasive for the reasons provided above.

Stopler and Shively could not be combined

Patent Owner argues that Shively and Stopler are incompatible and that it would not have been possible to incorporate Shively's bit-spreading concept into Stopler. PO Resp. 51. In particular, Patent Owner argues that Shively's bit-spreading concept is not compatible with Stopler's "diagonalization" technique. PO Resp. 51–55. This argument is misplaced as Petitioner did not rely on Stopler's "diagonalization" technique. Rather, Petitioner relies on Stopler's phase scrambler and scrambling technique. Pet. 15, 22–23. Moreover, Stopler describes its "diagonalization" technique as optional. Ex. 1012, 10:17, 13:1–3. For these reasons, we are not persuaded by Patent Owner's argument that it would not be possible to combine Shively and Stopler.

No "market forces" in effect to prompt Shively/Stopler combination

The Petition states that "[m]arket forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Pet. 16 (citing Ex. 1009, 29). Patent Owner argues that neither Petitioner nor Dr. Tellado identifies a single product or standard that employs any of the ideas disclosed in Shively or Stopler. PO Resp. 55–57.

Patent Owner's arguments are misplaced. It was not incumbent on Petitioner or Dr. Tellado to identify a product or standard that employs the ideas disclosed in Shively or Stopler in order to show that the combination of Shively and Stopler would have been obvious to a person skilled in the art. That is not the standard. Rather, a claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR*, 550 U.S. at 406. Dr. Tellado testified that a person having ordinary skill in the art would have been familiar with problems caused by a high PAR, that equipment needed to cope with PAR would have been expensive and inefficient, and that less capable equipment would have caused distortion such as from amplitude clipping. Ex. 1009 ¶ 66. He further testified that combining Shively's redundant bit transmission with Stopler's phase scrambling technique would have allowed for faster DSL modems without requiring more complex and expensive circuitry for handling increased PAR. *Id.* ¶ 69. Patent Owner has not presented sufficient evidence to undermine Dr. Tellado's testimony. Indeed, Dr. Short testified that a way to address high PAR in a communication system would be to use transceiver components that could handle higher peak transmission values, which would be expensive and power hungry. Ex. 1027, 45:15–46:12. Based on the record before us, we find that at the time of the invention, a person having ordinary skill in the art would have recognized that an increase in PAR would have been associated with more expensive communication equipment. Accordingly, a drive to reduce equipment costs would have motivated a person having ordinary skill in the art to include

Stopler's phase scrambler into Shively's transmitter to reduce PAR. Pet. 14–16 (citing Ex. 1009 ¶¶ 66–70).

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 1, 2, 4, 15, 16, and 18 of the '158 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler.

E. Asserted Obviousness over Shively, Stopler, and Gerszberg

Petitioner contends that claims 3, 5, 14, 17, 19, and 28–30 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 33–41. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, and Gerszberg meets all of the claim limitations. *Id.* (citing Ex. 1009).

Gerszberg discloses using a Digital Subscriber Line (DSL) modem, such as an ADSL modem, to transmit and receive modulated data. Ex. 1013, 11:66–12:7. The modem uses DMT modulation to transmit data. *Id.* at 12:7–9. Gerszberg further describes types of data services that may be provided to subscriber premises by a DSL modem that uses DMT modulation, such as high-speed internet access and video services. *Id.* at 7:44–60, 8:16–36, and 10:63–11:3. Gerszberg also describes that a DSL modem can be used in various DSL communications, such as HDSL, ADSL, SDSL, and VDSL. *Id.* at 9:66–10:3.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 3, 5, 14, 17, 19, and 28–30. Pet. 33–41. For example, claim 3 depends from claim 1 and recites "wherein one or more of the first transceiver and second transceiver are VDSL transceivers." Claim 17, which depends from independent claim 15, is similar to claim 3. Petitioner

relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (citing Ex. 1013, 9:62–10:3) (emphasis omitted). Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38 (citing Ex. 1009, 67). Moreover, Petitioner provides a rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 34–37. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 3, 5, 14, 17, 19, and 28–30 are unpatentable as obvious over Shively, Stopler, and Gerszberg.

F. Asserted Obviousness over Shively, Stopler, and Bremer

Petitioner contends that claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Bremer. Pet. 41–50. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, and Bremer allegedly meets all of the claim limitations. *Id*. (citing Ex. 1009).

Bremer relates to encoding and decoding techniques for a data signal that is transmitted over a communications channel. Ex. 1017, 1:41–67. Bremer describes using a pseudorandom generator to encode the gain or phase of a signal prior to transmission, and on the receiving end, uses a

second pseudorandom generator to decode the encoded data signal. *Id*. at 1:53–64.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 6, 9, 10, 12, 20, 23, 24, and 26. Pet. 41–50. For example, claim 6 depends from claim 1 and recites "independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver." Claim 20, which depends from independent claim 15, is similar to claim 6. Petitioner contends that Bremer teaches that when a transmitting device includes components causing a pseudorandom phase shift to the transmitted signal, a receiving device requires complementary components to decode the signal. Pet. 45 (citing Ex. 1017, 1:60–65, 4:33–34). Petitioner further contends that Bremer describes altering gain and phase modifiers of a data signal being transmitted from a QAM modem based on values from a pseudorandom signal generator, which generates a pseudorandom number. Pet. 45 (citing Ex. 1017, Abstract, 2:32; Ex. 1009, 77). Petitioner further contends that the values produced by a second pseudorandom number generator are independent of the values produced by a first pseudorandom number generator. Pet. 46 (citing Ex. 1017, 4:10–16, 4:35–36; Ex. 1009, 80). Petitioner provides rational reasoning for combining Bremer with the combined teachings of Shively and Stopler. Pet. 42–44.

Notwithstanding Patent Owner's arguments, which we address immediately below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable as obvious over Shively, Stopler, and Bremer.

Patent Owner's Contentions

Patent Owner argues that Petitioner fails to allege a legally sufficient rationale for combining Bremer's single-carrier privacy modem system, and for modifying it such that it would have been compatible with Shively/Stopler's multicarrier systems. PO Resp. 59–60. We are not persuaded by this argument.

As explained above, Petitioner relies on Bremer for its teaching of a second pseudo-random number generator to meet the limitations of claims 6 and 20. Patent Owner quotes the reasons provided in the Petition at pages 46–47 for combining Bremer with the Shively/Stopler combination and argues that Petitioner's allegations present more questions than answers. *Id*. at 60. Patent Owner argues that Dr. Tellado provides no additional guidance. *Id*. (citing Ex. 1009, 81). We disagree with Patent Owner that Petitioner failed to provide a sufficient rationale and reasoning for modifying the combined teachings of Shively and Stopler with Bremer.

Patent Owner's focus on one passage from the Petition and one passage from Dr. Tellado's testimony overlooks other supported contentions made by Petitioner. In particular, the Petition explains that a person having ordinary skill in the art would have understood that the transceivers and receivers described in both Stopler and Shively would have been a matched pair and that the techniques used by a transmitter to encode data for transmission would have been paralleled by techniques used by a receiver to decode data. Pet. 42–43 (citing Ex. 1009, 74; Ex. 1017, 1:60–63). The Petition further explains that a person having ordinary skill in the art would have understood that a receiver must be able to reverse the phase modification applied by a transmitter. Pet. 43 (citing Ex. 1009, 75; Ex.

1017, 1:34–36). Petitioner explains that the combination of Shively, Stopler, and Bremer would have been obvious to a person of ordinary skill in the art because it is the application of a known technique (designing a receiver to match a transmitter) to improve a similar system in the same way (allowing data to be received). Pet. 44 (citing Ex. 1009, 76). Moreover, Dr. Tellado testified that "[a]lthough Bremer describes a single-carrier QAM communication system, it would have been obvious to a POSITA that Bremer's teaching of a complementary pseudo-random number generator, and performing complementary changes of the received signal, could be applied on a carrier-by-carrier basis to the multicarrier system of Stopler." Ex. 1009, 81. We agree with Petitioner's reasoning and rationale provided, and determine it would have been obvious to include Bremer's second pseudo-random number generator in the combined Shively/Stopler system receiver in order to decode and receive the phase scrambled data transmitted by the system transceiver. Ex. 1009, 73–76, 81.

G. Asserted Obviousness over Shively, Stopler, Bremer, and Gerszberg

Petitioner contends that claims 8, 11, 13, 22, 25, and 27 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Gerszberg. Pet. 50–53. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Gerszberg allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 8, 11, 13, 22, 25, and 27. Pet. 50–53. For example, claim 11 depends from claim 6, and recites "wherein the first and second transceivers are VDSL transceivers." Claim 25, which depends from claim

20, is similar to claim 11. Petitioner relies on Gerszberg's description that its "DSL modem may be constructed using any of the techniques described in the applications incorporated by reference below" such as "High Speed Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL) and Very high data rate Digital Subscriber Line (VDSL)." Pet. 37–38 (emphasis omitted) (citing Ex. 1013, 9:62–10:3). Petitioner contends that it would have been obvious to replace Shively's ADSL modems with VDSL modems, as taught by Gerszberg, in order to achieve higher bandwidth. Pet. 38, 52 (citing Ex. 1009, 67, 89). Moreover, Petitioner provides a rational reason for combining Gerszberg with the combined teachings of Shively and Stopler. Pet. 50–51. Patent Owner does not present arguments for any of those claims separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 8, 11, 13, 22, 25, and 27 are unpatentable as obvious over Shively, Stopler, Bremer, and Gerszberg.

H. Asserted Obviousness over Shively, Stopler, Bremer, and Flammer

Petitioner contends that claims 7 and 21 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, Bremer, and Flammer. Pet. 53–60. Relying on the testimony of Dr. Jose Tellado, Petitioner explains how the combination of Shively, Stopler, Bremer, and Flammer allegedly meets all of the claim limitations. *Id.* (citing Ex. 1009).

Flammer relates to data transmission between a source node and a target node, where each node has a transmitter and a receiver. Ex. 1019, Abstract. Flammer uses pseudo-random number generators in its communication system. Flammer describes synchronization between

pseudo-random number generators at different ends of a communication channel. *Id.* at 3:49–4:10. As part of the synchronization, an acquisition/ synchronization packet is transmitted that includes a seed value from the source node to the target node. *Id.* at 3:52–58. The transmitted seed value is used to initialize the pseudo-random number generators executing at the respective source and target nodes. *Id.* at 3:52–4:9. Once the pseudo-random number generators at both the source node and the target node have the same seed value, they can generate identical pseudo-random number sequences for selecting frequency bands. *Id.* at 4:42–53.

Based on the record before us, Petitioner has accounted sufficiently for dependent claims 7 and 21. Pet. 50–53. Claim 7 depends from claim 6 and recites "using in the first and second transceivers a same seed for the first and second pseudo-random number generators and the value of the seed is transmitted from the first transceiver to the second transceiver." Claim 21, which depends from claim 20, is similar to claim 7. Petitioner contends that Flammer teaches a transceiver as a node having a transmitter and a receiver. Pet. 57 (citing Ex. 1019, Abstract). Petitioner further contends that in Flammer, the source node is the first transceiver and the target node is the second transceiver. Ex. 1009, 92. Petitioner argues that Flammer teaches that it was known for the pseudo-random number generators in the source node and the target node to use the same seed value. Pet. 57 (citing Ex. 1019, 3:52–67; Ex. 1009, 92–93). Petitioner further explains, with supporting evidence, that Flammer teaches transmitting a value of a seed from a source node (a first transceiver) to a target node (a second transceiver) when the target node receives an acquisition/synchronization packet which contains information about the node, including a seed value.

Moreover, Petitioner provides a rational reason for combining Flammer with the combined teachings of Shively, Stopler, and Bremer. Pet. 54–57. Patent Owner does not present arguments for either of claims 7 and 21 separate from the arguments addressed previously.

We are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 7 and 21 are unpatentable as obvious over Shively, Stopler, Bremer, and Flammer.

I. Patent Owner's Motion to Exclude

Patent Owner moves to exclude Exhibits 1022–1025, 1028, and portions of 1026 and 2013. PO Mot. Exc. Exhibit 1022 is styled "Robert T. Short, 'Physical Layer,' *in* WIMEDIA UWB (2008)." Pet. Reply 5. Patent Owner argues that we should exclude Exhibit 1022 as irrelevant. PO Mot. Exc. 2–4. Exhibit 1022 was not cited or discussed in any way in Petitioner's Reply. Moreover, we did not rely on Exhibits 1022 in rendering our decision. We did not and need not consider Exhibit 1022. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Exhibit 1023 is styled "Denis J. G. Mestdagh and Paul M. P. Spruyt, 'A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions on Communications*, Vol. 44, No. 10, (October 1996)." Pet. Reply 5. Exhibit 1024 is styled "Stefan H. Muller and Johannes B. Huber, 'A Comparison of Peak Power Reduction Schemes for OFDM,' IEEE Global Telecommunications Conference (1997)." *Id*. Exhibit 1028 is styled "T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected

pages)." *Id*. Exhibit 2013 is a copy of the cross examination transcript of Dr. Tellado.

Patent Owner argues that we should exclude Exhibits 1023, 1024, and 1028 in their entirety as irrelevant. PO Mot. Exc. 9–12. Patent Owner also argues that we should exclude certain portions of Exhibit 2013 allegedly discussing Exhibits 1023, 124, or 1028. *Id*. Although Exhibits 1023, 1024, and 1028 are mentioned briefly in Petitioner's Reply, we did not rely on Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013 in rendering our decision. We did not and need not consider Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Exhibit 1025 is a copy of Dr. Tellado's thesis. Pet. Reply 5. Patent Owner argues that we should exclude Exhibit 1025 as irrelevant. PO Mot. Exc. 4–6. Exhibit 1025 was not cited or discussed in any way in Petitioner's Reply. Moreover, we did not rely on Exhibits 1025 in rendering our decision. We did not and need not consider Exhibit 1025. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Lastly, Patent Owner seeks to exclude paragraphs 16 (last two sentences), 29, 42, 43 (first sentence), and 52 of Exhibit 1026 (Second Tellado Declaration), and certain portions of Dr. Tellado's cross examination transcript (Exhibit 2013). PO Mot. Exc. 6–9. We did not rely on the objected to portions of Exhibits 1026 or 2013 in rendering our

decision. We did not and need not consider the objected to portions of Exhibits 1026 or 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

For all of the above reasons, we *dismiss* Patent Owner's Motion to Exclude.

J. Motion for Observations

Patent Owner also filed a Motion for Observations (Paper 30, "PO Mot. Obs."), to which Petitioner filed a Response (Paper 37, "Pet. Resp."). To the extent Patent Owner's Motion for Observations pertains to testimony purportedly impacting Dr. Tellado's credibility, we have considered Patent Owner's observations and Petitioner's responses in rendering this Final Written Decision, and accorded Dr. Tellado's testimony appropriate weight in view of Patent Owner's observations and Petitioner's response to those observations. *See* Obs. 1–13; Obs. Resp. 2–11.

III. CONCLUSION

Based on the evidence and arguments, Petitioner has demonstrated by a preponderance of the evidence that claims 1, 2, 4, 15, 16, and 18 are unpatentable over Shively and Stopler; claims 3, 5, 14, 17, 19, and 28–30 are unpatentable over Shively, Stopler, and Gerszberg; claims 6, 9, 10, 12, 20, 23, 24, and 26 are unpatentable over Shively, Stopler, and Bremer; claims 8, 11, 13, 22, 25, and 27 are unpatentable over Shively, Stopler, Bremer, and Gerszberg; and claims 7 and 21 are unpatentable over Shively, Stopler, Bremer, and Flammer.

IV. ORDER

Accordingly, it is:

ORDERED that claims 1–30 of the '158 patent have been shown to be unpatentable;

FURTHER ORDERED that Patent Owner's Motion to Exclude is *dismissed*; and

FURTHER ORDERED that, because this is a final written decision, parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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UNITED STATES COURT OF APPEALS
FOR THE FEDERAL CIRCUIT

TQ Delta, LLC
Patent Owner/Appellant

Appeal No. 18-1766
18-1767

v.

Cisco Systems, Inc., Dish Network, LLC,
Comcast Cable Communications, LLC,
Cox Communications, Inc.,
Time Warner Cable Enterprises LLC,
Verizon Services Corp., and Arris Group,
Inc. Petitioner/Appellee

Proceeding Nos: IPR2016-01020 and IPR2016-01021

NOTICE FORWARDING CERTIFIED LIST

A Notice of Appeal to the United States Court of Appeals for the Federal Circuit was timely filed on April 2, 2018, in the United States Patent and Trademark Office in connection with the above identified *Inter Partes* Review (IPR) proceeding. Pursuant to 35 U.S.C. § 143, a Certified List is this day being forwarded to the Federal Circuit.

May 14, 2018

Respectfully submitted,

Under Secretary of Commerce for Intellectual Property and Director of the United States Patent and Trademark Office

By: Candice Kilby

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that a true and correct copy of the foregoing has been served on Appellant and Appellee this 14th day of May, 2018, as follows:

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U.S. DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

May 14, 2018

THIS IS TO CERTIFY that the attached document is a list of the papers that comprise the record before the Patent Trial and Appeal Board (PTAB) for the *Inter Partes* Review proceeding identified below:

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., AND ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case: IPR2016-01020
IPR2016-01021
Patent 9,014,243 B2
Patent 8,718,158 B2

By authority of the
DIRECTOR OF THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Candice Killey

Certifying Officer

Prosecution History for IPR2016-01020

Filing Date	Document
05/09/2016	Petition for *Inter Partes* Review
05/09/2016	Petitioner Power of Attorney
05/12/2016	Notice of Filing Date Accorded to Petition
05/27/2016	Patent Owner Power of Attorney
05/27/2016	Patent Owner Mandatory Notices
08/12/2016	Patent Owner Preliminary Response
11/04/2016	Scheduling Order
11/04/2016	Decision - Institution of *Inter Partes* Review
01/09/2017	Joint Stipulation to Move Due Dates
01/25/2017	Petitioner Mandatory Notices
01/25/2017	Patent Owner Notice of Deposition of Tellado
02/24/2017	Patent Owner Response
02/24/2017	Patent Owner Exhibit List
02/27/2017	Decision - Institution of *Inter Partes* Review and Motion for Joinder (IPR2017-00254)
04/03/2017	Decision - Institution of *Inter Partes* Review and Motion for Joinder (IPR2017-00418)
04/18/2017	Petitioner Notice of Deposition of Dr. Short
06/08/2017	Petitioner Reply
06/13/2017	Patent Owner Second Notice of Deposition of Dr. Tellado
06/14/2017	Petitioner Mandatory Notices
06/15/2017	Patent Owner Objections to Evidence
06/22/2017	Order - Conduct of the Proceeding
06/27/2017	Patent Owner Listing of Improper Reply/New Argument Evidence
06/27/2017	Patent Owner Exhibit List
06/28/2017	Petitioner Exhibit List
06/30/2017	Petitioner Request for Oral Hearing
06/30/2017	Patent Owner Request for Oral Argument
06/30/2017	Patent Owner Motion for Observation Regarding Cross-Examination of Dr. Tellado

Filing Date	Document
06/30/2017	Patent Owner Motion to Exclude
07/03/2017	Petitioner Itemized Listing Pursuant to Paper 21
07/07/2017	Order - Authorization to File Motion
07/14/2017	Patent Owner Motion for Discovery
07/14/2017	Patent Owner Exhibit List
07/14/2017	Petitioner Opposition to Patent Owner Motion to Exclude
07/14/2017	Petitioner Response to Patent Owner Motion for Observation on Cross-Examination
07/20/2017	Trial Hearing Order
07/21/2017	Petitioner Opposition to Patent Owner Motion for Discovery
07/21/2017	Patent Owner Reply in Support of Motion to Exclude
08/01/2017	Patent Owner Objections to Petitioners Demonstratives
08/21/2017	Oral Hearing Transcript
10/26/2017	Decision - Motion for Additional Discovery
10/26/2017	Final Written Decision
11/27/2017	Patent Owner Request for Rehearing
02/01/2018	Decision - Request for Rehearing
04/02/2018	Patent Owner Notice of Appeal to the U.S. Court of Appeals for the Federal Circuit
04/20/2018	Petitioner Mandatory Notices

Prosecution History for IPR2016-01021

Filing Date	Document
05/09/2016	Petition for *Inter Partes* Review
05/09/2016	Petitioner Power of Attorney
05/12/2016	Notice of Filing Date Accorded to Petition
05/27/2016	Patent Owner Power of Attorney
05/27/2016	Patent Owner Mandatory Notices
08/12/2016	Patent Owner Preliminary Response
11/04/2016	Decision - Institution of *Inter Partes* Review
11/04/2016	Scheduling Order
01/09/2017	Joint Stipulation to Move Due Dates
01/25/2017	Petitioner Mandatory Notices
01/25/2017	Patent Owner Notice of Deposition of Dr. Tellado
01/25/2017	Patent Owner Corrected Notice of Deposition of Dr. Tellado
02/14/2017	Decision - Institution of *Inter Partes* Review and Motion for Joinder (IPR2017-00255)
02/20/2017	Petitioner Mandatory Notice
02/24/2017	Patent Owner Response
02/24/2017	Patent Owner Exhibit List
02/27/2017	Patent Owner Corrected Exhibit List
04/03/2017	Decision - Institution of *Inter Partes* Review and Motion for Joinder (IPR2017-00417)
04/18/2017	Petitioner Notice of Deposition of Dr. Short
06/08/2017	Petitioner Reply
06/13/2017	Patent Owner Second Notice of Deposition of Dr. Tellado
06/14/2017	Petitioner Mandatory Notices
06/15/2017	Patent Owner Objections to Evidence
06/22/2017	Order - Conduct of the Proceeding
06/27/2017	Patent Owner Listing of Improper Reply/New Argument and Evidence
06/27/2017	Patent Owner Exhibit List
06/28/2017	Petitioner Exhibit List
06/30/2017	Petitioner Request for Oral Hearing

Filing Date	Document
06/30/2017	Patent Owner Request for Oral Argument
06/30/2017	Patent Owner Motion for Observation Regarding Cross-Examination of Dr. Tellado
06/30/2017	Patent Owner Motion to Exclude
07/03/2017	Petitioner Itemized Listing Pursuant to Paper 24
07/07/2017	Order - Authorization to File Motion
07/14/2017	Patent Owner Motion for Discovery
07/14/2017	Patent Owner Exhibit List
07/14/2017	Petitioner Opposition to Patent Owner Motion to Exclude
07/14/2017	Petitioner Response to Patent Owner Motion for Observation on Cross-Examination
07/20/2017	Trial Hearing Order
07/21/2017	Petitioner Opposition to Patent Owner Motion for Discovery
07/21/2017	Patent Owner Reply in Support of Motion to Exclude
08/01/2017	Patent Owner Objections to Petitioners Demonstratives
08/21/2017	Oral Hearing Transcript
10/26/2017	Decision - Motion for Additional Discovery
10/26/2017	Final Written Decision
11/27/2017	Patent Owner Request for Rehearing
02/01/2018	Decision - Rehearing Request
04/02/2018	Patent Owner Notice of Appeal to U.S. Court of Appeals for the Federal Circuit
04/20/2018	Petitioner Mandatory Notices

US008718158B2

(12) **United States Patent**
Tzannes

(10) **Patent No.: US 8,718,158 B2**
(45) **Date of Patent: May 6, 2014**

(54) **SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM**

(75) Inventor: **Marcos C. Tzannes**, Orinda, CA (US)

(73) Assignee: **TQ Delta, LLC**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 9 days.

(21) Appl. No.: **13/303,417**

(22) Filed: **Nov. 23, 2011**

(65) **Prior Publication Data**

US 2012/0069878 A1 Mar. 22, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/783,725, filed on May 20, 2010, now Pat. No. 8,090,008, which is a continuation of application No. 12/255,713, filed on Oct. 22, 2008, now Pat. No. 7,769,104, which is a continuation of application No. 11/863,581, filed on Sep. 28, 2007, now Pat. No. 7,471,721, which is a continuation of application No. 11/211,535, filed on Aug. 26, 2005, now Pat. No. 7,292,627, which is a continuation of application No. 09/710,310, filed on Nov. 9, 2000, now Pat. No. 6,961,369.

(60) Provisional application No. 60/164,134, filed on Nov. 9, 1999.

(51) **Int. Cl.**
H04K 1/10 (2006.01)
H04L 27/28 (2006.01)

(52) **U.S. Cl.**
USPC **375/260**; 375/222; 375/219; 375/220; 375/295; 375/316; 370/203; 370/527; 370/208

(58) **Field of Classification Search**
USPC 375/222, 219, 220, 295, 316, 259, 260; 370/203, 527, 208
See application file for complete search history.

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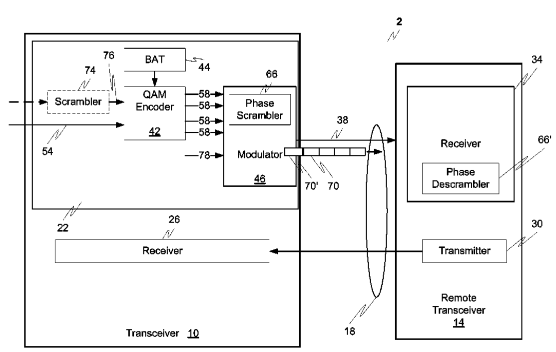
(Continued)

Primary Examiner — Phuong Phu
(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

A system and method that scrambles the phase characteristic of a carrier signal are described. The scrambling of the phase characteristic of each carrier signal includes associating a value with each carrier signal and computing a phase shift for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristic of the carrier signals. Bits of an input signal are modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced PAR.

30 Claims, 2 Drawing Sheets



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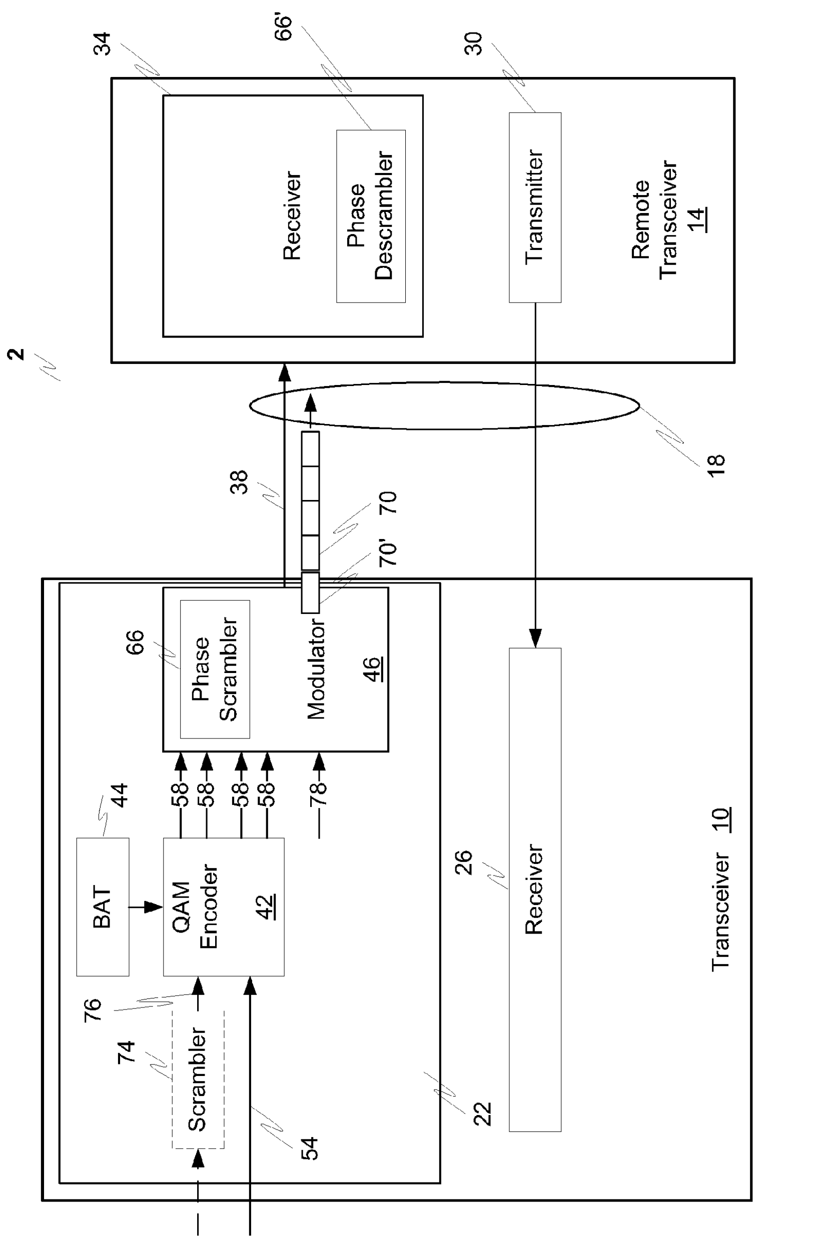
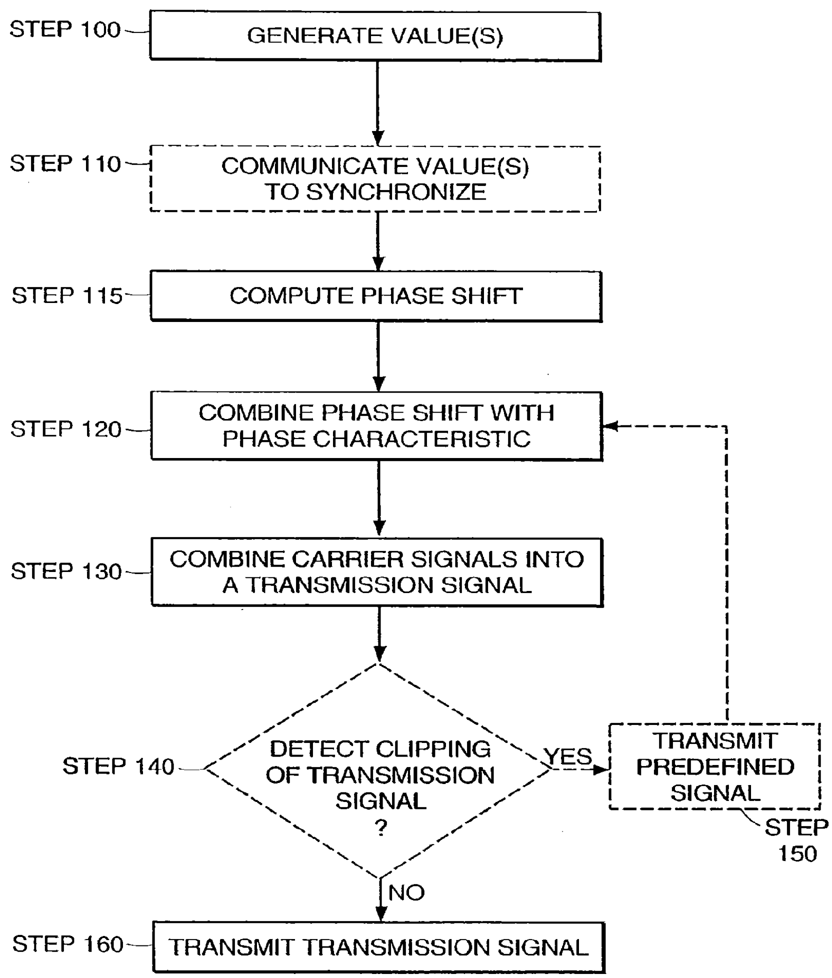


Receiver
Phase Descrambler
Transmitter
Remote Transceiver 14
Phase Scrambler
Modulator
46
BAT
QAM Encoder
42
Scrambler
Receiver
Transceiver 10
34
66'
30
2
38
70
70'
18
66
44
58
78
76
74
26
22
54

FIG. 1



STEP 100
GENERATE VALUE(S)
STEP 110
COMMUNICATE VALUE(S) TO SYNCHRONIZE
STEP 115
COMPUTE PHASE SHIFT
STEP 120
COMBINE PHASE SHIFT WITH PHASE CHARACTERISTIC
STEP 130
COMBINE CARRIER SIGNALS INTO A TRANSMISSION SIGNAL
STEP 140
DETECT CLIPPING OF TRANSMISSION SIGNAL ?
YES
TRANSMIT PREDEFINED SIGNAL
STEP 150
NO
STEP 160
TRANSMIT TRANSMISSION SIGNAL

FIG. 2

SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM

RELATED APPLICATION

This application is a Continuation of U.S. patent application Ser. No. 12/783,725, filed May 20, 2010, now U.S. Pat. No. 8,090,008, which is a Continuation of U.S. patent application Ser. No. 12/255,713, filed Oct. 22, 2008, now U.S. Pat. No. 7,769,104, which is a Continuation of U.S. patent application Ser. No. 11/863,581, filed Sep. 28, 2007, now U.S. Pat. No. 7,471,721, which is a Continuation of U.S. application Ser. No. 11/211,535, filed Aug. 26, 2005, now U.S. Pat. No. 7,292,627, which is a Continuation of U.S. patent application Ser. No. 09/710,310, filed Nov. 9, 2000, now U.S. Pat. No. 6,961,369, which claims the benefit of the filing date of copending U.S. Provisional Application Ser. No. 60/164,134, filed Nov. 9, 1999, entitled "A Method For Randomizing The Phase Of The Carriers In A Multicarrier Communications System To Reduce The Peak To Average Power Ratio Of The Transmitted Signal," each of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

BACKGROUND OF THE INVENTION

In a conventional multicarrier communications system, transmitters communicate over a communication channel using multicarrier modulation or Discrete Multitone Modulation (DMT). Carrier signals (carriers) or sub-channels spaced within a usable frequency band of the communication channel are modulated at a symbol (i.e., block) transmission rate of the system. An input signal, which includes input data bits, is sent to a DMT transmitter, such as a DMT modem. The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals using an Inverse Fast Fourier Transform (IFFT) to generate a time domain signal, or transmission signal, that represents the input signal. The DMT transmitter transmits the transmission signal, which is a linear combination of the multiple carriers, to a DMT receiver over the communication channel.

The phase and amplitude of the carrier signals of DMT transmission signal can be considered random because the phase and amplitude result from the modulation of an arbitrary sequence of input data bits comprising the transmitted information. Therefore, under the condition that the modulated data bit stream is random, the DMT transmission signal can be approximated as having a Gaussian probability distribution. A bit scrambler is often used in the DMT transmitter to scramble the input data bits before the bits are modulated to assure that the transmitted data bits are random and, consequently, that the modulation of those bits produces a DMT transmission signal with a Gaussian probability distribution.

With an appropriate allocation of transmit power levels to the carriers or sub-channels, such a system provides a desirable performance. Further, generating a transmission signal with a Gaussian probability distribution is important in order to transmit a transmission signal with a low peak-to-average ratio (PAR), or peak-to-average power ratio. The PAR of a transmission signal is the ratio of the instantaneous peak value (i.e., maximum magnitude) of a signal parameter (e.g., voltage, current, phase, frequency, power) to the time-averaged value of the signal parameter. In DMT systems, the PAR of the transmitted signal is determined by the probability of the random transmission signal reaching a certain peak voltage during the time interval required for a certain number of symbols. An example of the PAR of a transmission signal transmitted from a DMT transmitter is 14.5 dB, which is equivalent to having a 1E-7 probability of clipping. The PAR of a transmission signal transmitted and received in a DMT communication system is an important consideration in the design of the DMT communication system because the PAR of a signal affects the communication system's total power consumption and component linearity requirements of the system.

If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, multiple carrier signals are used to modulate the same input data bits, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a −90 degree phase characteristic of the DMT carrier signal). An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal. Thus, there remains a need for a system and method that can effectively scramble the phase of the modulated carrier signals in order to provide a low PAR for the transmission signal.

SUMMARY OF THE INVENTION

The present invention features a system and method that scrambles the phase characteristics of the modulated carrier signals in a transmission signal. In one aspect, a value is associated with each carrier signal. A phase shift is computed for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals.

In one embodiment, the input bit stream is modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced peak-to-average power ratio (PAR). The value is derived from a predetermined parameter, such as a random number generator, a carrier number, a DMT symbol count, a superframe count, and a hyperframe count. In another embodiment, a predetermined transmission signal is transmitted when the amplitude of the transmission signal exceeds a certain level.

In another aspect, the invention features a method wherein a value is associated with each carrier signal. The value is determined independently of any input bit value carried by that carrier signal. A phase shift for each carrier signal is computed based on the value associated with that carrier signal. The transmission signal is demodulated using the phase shift computed for each carrier signal.

In another aspect, the invention features a system comprising a phase scrambler that computes a phase shift for each carrier signal based on a value associated with that carrier signal. The phase scrambler also combines the phase shift computed for each carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase char-

acteristic of the carrier signals. In one embodiment, a modulator, in communication with the phase scrambler, modulates bits of an input signal onto the carrier signals having the substantially scrambled phase characteristics to produce a transmission signal with a reduced PAR.

DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. The advantages of the invention described above, as well as further advantages of the invention, may be better understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a block diagram of an embodiment of a digital subscriber line communications system including a DMT (discrete multitone modulation) transceiver, in communication with a remote transceiver, having a phase scrambler for substantially scrambling the phase characteristics of carrier signals; and

FIG. **2** is a flow diagram of an embodiment of a process for scrambling the phase characteristics of the carrier signals in a transmission signal.

DETAILED DESCRIPTION

FIG. **1** shows a digital subscriber line (DSL) communication system **2** including a discrete multitone (DMT) transceiver **10** in communication with a remote transceiver **14** over a communication channel **18** using a transmission signal **38** having a plurality of carrier signals. The DMT transceiver **10** includes a DMT transmitter **22** and a DMT receiver **26**. The remote transceiver **14** includes a transmitter **30** and a receiver **34**. Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM).

The communication channel **18** provides a downstream transmission path from the DMT transmitter **22** to the remote receiver **34**, and an upstream transmission path from the remote transmitter **30** to the DMT receiver **26**. In one embodiment, the communication channel **18** is a pair of twisted wires of a telephone subscriber line. In other embodiments, the communication channel **18** can be a fiber optic wire, a quad cable, consisting of two pairs of twisted wires, or a quad cable that is one of a star quad cable, a Dieselhorst-Martin quad cable, and the like. In a wireless communication system wherein the transceivers **10**, **14** are wireless modems, the communication channel **18** is the air through which the transmission signal **38** travels between the transceivers **10**, **14**.

By way of example, the DMT transmitter **22** shown in FIG. **1** includes a quadrature amplitude modulation (QAM) encoder **42**, a modulator **46**, a bit allocation table (BAT) **44**, and a phase scrambler **66**. The DMT transmitter **22** can also include a bit scrambler **74**, as described further below. The remote transmitter **30** of the remote transceiver **14** comprises equivalent components as the DMT transmitter **22**. Although this embodiment specifies a detailed description of the DMT transmitter **22**, the inventive concepts apply also to the receivers **34**, **24** which have similar components to that of the DMT transmitter **22**, but perform inverse functions in a reverse order.

The QAM encoder **42** has a single input for receiving an input serial data bit stream **54** and multiple parallel outputs to transmit QAM symbols **58** generated by the QAM encoder **42** from the bit stream **54**. In general, the QAM encoder **42** maps the input serial bit-stream **54** in the time domain into parallel QAM symbols **58** in the frequency domain. In particular, the QAM encoder **42** maps the input serial data bit stream **54** into N parallel quadrature amplitude modulation (QAM) constellation points **58**, or QAM symbols **58**, where N represents the number of carrier signals generated by the modulator **46**. The BAT **44** is in communication with the QAM encoder **42** to specify the number of bits carried by each carrier signal. The QAM symbols **58** represent the amplitude and the phase characteristic of each carrier signal.

The modulator **46** provides functionality associated with the DMT modulation and transforms the QAM symbols **58** into DMT symbols **70** each comprised of a plurality of time-domain samples. The modulator **46** modulates each carrier signal with a different QAM symbol **58**. As a result of this modulation, carrier signals have phase and amplitude characteristics based on the QAM symbol **58** and therefore based on the input-bit stream **54**. In particular, the modulator **46** uses an inverse fast Fourier transform (IFFT) to change the QAM symbols **58** into a transmission signal **38** comprised of a sequence of DMT symbols **70**. The modulator **46** changes the QAM symbols **58** into DMT symbols **70** through modulation of the carrier signals. In another embodiment, the modulator **46** uses the inverse discrete Fourier transform (IDFT) to change the QAM symbols **58** into DMT symbols **70**. In one embodiment, a pilot tone is included in the transmission signal **38** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the transmission signal **38**.

The modulator **46** also includes a phase scrambler **66** that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristic of that carrier signal. Combining phase shifts with phase characteristics, in accordance with the principles of the invention, substantially scrambles the phase characteristics of the carrier signals in the transmission signal **38**. By scrambling the phase characteristics of the carrier signals, the resulting transmission signal **38** has a substantially minimized peak-to-average (PAR) power ratio. The phase scrambler **66** can be part of or external to the modulator **46**. Other embodiments of the phase scrambler **66** include, but are not limited to, a software program that is stored in local memory and is executed on the modulator **46**, a digital signal processor (DSP) capable of performing mathematical functions and algorithms, and the like. The remote receiver **34** similarly includes a phase descrambler **66'** for use when demodulating carrier signals that have had their phase characteristics adjusted by the phase scrambler **66** of the DMT transceiver **10**.

To compute a phase shift for each carrier signal, the phase scrambler **66** associates one or more values with that carrier signal. The phase scrambler **66** determines each value for a carrier signal independently of the QAM symbols **58**, and, therefore, independently of the bit value(s) modulated onto the carrier signal. The actual value(s) that the phase scrambler **66** associates with each carrier signal can be derived from one or more predefined parameters, such as a pseudo-random number generator (pseudo-RNG), a DMT carrier number, a DMT symbol count, a DMT superframe count, a DMT hyperframe count, and the like, as described in more detail below. Irrespective of the technique used to produce each value, the same technique is used by the DMT transmitter **22** and the remote receiver **34** so that the value associated with a given carrier signal is known at both ends of the communication channel **18**.

The phase scrambler **66** then solves a predetermined equation to compute a phase shift for the carrier signal, using the

value(s) associated with that carrier signal as input that effects the output of the equation. Any equation suitable for computing phase shifts can be used to compute the phase shifts. When the equation is independent of the bit values of the input serial bit stream **54**, the computed phase shifts are also independent of such bit values.

In one embodiment (shown in phantom), the DMT transmitter **22** includes a bit scrambler **74**, which receives the input serial bit stream **54** and outputs data bits **76** that are substantially scrambled. The substantially scrambled bits **76** are then passed to the QAM encoder **42**. When the bit scrambler **74** is included in the DMT transmitter **22**, the operation of the phase scrambler **66** further assures that the transmission signal **38** has a Gaussian probability distribution and, therefore, a substantially minimized PAR.

FIG. **2** shows embodiments of a process used by the DMT transmitter **22** for adjusting the phase characteristic of each carrier signal and combining these carrier signals to produce the transmission signal **38**. The DMT transmitter **22** generates (step **100**) a value that is associated with a carrier signal. Because the value is being used to alter the phase characteristics of the carrier signal, both the DMT transmitter **22** and the remote receiver **34** must recognize the value as being associated with the carrier signal. Either the DMT transmitter **22** and the remote receiver **34** independently derive the associated value, or one informs the other of the associated value. For example, in one embodiment the DMT transmitter **22** can derive the value from a pseudo-RNG and then transmit the generated value to the remote receiver **34**. In another embodiment, the remote receiver **34** similarly derives the value from the same pseudo-RNG and the same seed as used by the transmitter (i.e., the transmitter pseudo-RNG produces the same series of random numbers as the receiver pseudo-RNG).

As another example, the DMT transmitter **22** and the remote receiver **34** can each maintain a symbol counter for counting DMT symbols. The DMT transmitter **22** increments its symbol counter upon transmitting a DMT symbol; the remote receiver **34** upon receipt. Thus, when the DMT transmitter **22** and the remote receiver **34** both use the symbol count as a value for computing phase shifts, both the DMT transmitter **22** and remote receiver **34** "know" that the value is associated with a particular DMT symbol and with each carrier signal of that DMT symbol.

Values can also be derived from other types of predefined parameters. For example, if the predefined parameter is the DMT carrier number, then the value associated with a particular carrier signal is the carrier number of that signal within the DMT symbol. The number of a carrier signal represents the location of the frequency of the carrier signal relative to the frequency of other carrier signals within a DMT symbol. For example, in one embodiment the DSL communication system **2** provides 256 carrier signals, each separated by a frequency of 4.3125 kHz and spanning the frequency bandwidth from 0 kHz to 1104 kHz. The DMT transmitter **22** numbers the carrier signals from 0 to 255. Therefore, "DMT carrier number 50" represents the 51st DMT carrier signal which is located at the frequency of 215.625 kHz (i.e., 51×4.3125 kHz).

Again, the DMT transmitter **22** and the remote receiver **34** can know the value that is associated with the carrier signal because both the DMT transmitter **22** and the remote receiver **34** use the same predefined parameter (here, the DMT carrier number) to make the value-carrier signal association. In other embodiments (as exemplified above with the transmitter pseudo-RNG), the DMT transmitter **22** can transmit the value to the remote receiver **34** (or vice versa) over the communication channel **18**.

In other embodiments, other predefined parameters can be used in conjunction with the symbol count. One example of such a predefined parameter is the superframe count that increments by one every 69 DMT symbols. One exemplary implementation that achieves the superframe counter is to perform a modulo 68 operation on the symbol count. As another example, the DMT transmitter **22** can maintain a hyperframe counter for counting hyperframes. An exemplary implementation of the hyperframe count is to perform a modulo 255 operation on the superframe count. Thus, the hyperframe count increments by one each time the superframe count reaches 255.

Accordingly, it is seen that some predefined parameters produce values that vary from carrier signal to carrier signal. For example, when the predefined parameter is the DMT carrier number, values vary based on the frequency of the carrier signal. As another example, the pseudo-RNG generates a new random value for each carrier signal.

Other predefined parameters produce values that vary from DMT symbol **70** to DMT symbol **70**. For example, when the predefined parameter is the symbol count, the superframe count, or hyperframe count, values vary based on the numerical position of the DMT symbol **70** within a sequence of symbols, superframes, or hyperframes. Predefined parameters such as the pseudo-RNG, symbol count, superframe count, and superframe can also be understood to be parameters that vary values over time. Any one or combination of the predefined parameters can provide values for input to the equation that computes a phase shift for a given carrier signal.

In one embodiment, the phase scrambling is used to avoid clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. In this embodiment, the DMT transmitter **22** uses a value based on a predefined parameter that varies over time, such as the symbol count, to compute the phase shift. It is to be understood that other types of predefined parameters that vary the values associated with carrier signals can be used to practice the principles of the invention. As described above, the transceivers **10**, **14** may communicate (step **110**) the values to synchronize their use in modulating and demodulating the carrier signals.

The DMT transmitter **22** then computes (step **115**) the phase shift that is used to adjust the phase characteristic of each carrier signal. The amount of the phase shift combined with the phase characteristic of each QAM-modulated carrier signal depends upon the equation used and the one or more values associated with that carrier signal.

The DMT transmitter **22** then combines (step **120**) the phase shift computed for each carrier signal with the phase characteristic of that carrier signal. By scrambling the phase characteristics of the carrier signals, the phase scrambler **66** reduces (with respect to unscrambled phase characteristics) the combined PAR of the plurality of carrier signals and, consequently, the transmission signal **38**. The following three phase shifting examples, PS #1-PS #3, illustrate methods used by the phase scrambler **66** to combine a computed phase shift to the phase characteristic of each carrier signal.

Phase Shifting Example #1

Phase shifting example #1 (PS #1) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$N \times \frac{\pi}{3},$$

modulo (mod) 2π. In this example, a carrier signal having a carrier number N equal to 50 has a phase shift added to the phase characteristic of that carrier signal equal to

$$50 \times \frac{\pi}{3}(\mathrm{mod}2\pi) = \frac{2}{3}\pi.$$

The carrier signal with a carrier number N equal to 51 has a phase shift added to the phase characteristic of that carrier signal equal to

$$51 \times \frac{\pi}{3}(\mathrm{mod}2\pi) = \pi.$$

The carrier signal with the carrier number N equal to 0 has no phase shift added to the phase characteristic of that carrier signal.

Phase Shifting Example #2

Phase shifting example #2 (PS #2) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(N + M) \times \frac{\pi}{4},$$

mod 2π, where M is the symbol count. In this example, a carrier signal having a carrier number N equal to 50 on DMT symbol count M equal to 8 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50 + 8) \times \frac{\pi}{4}(\mathrm{mod}2\pi) = \frac{\pi}{2}.$$

The carrier signal with the same carrier number N equal to 50 on the next DMT symbol count M equal to 9 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50 + 9) \times \frac{\pi}{4}(\mathrm{mod}2\pi) = \frac{3\pi}{4}.$$

Phase Shifting Example #3

Phase shifting example #3 (PS #3) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(X_N) \times \frac{\pi}{6},$$

mod 2π, where X_N is an array of N pseudo-random numbers. In this example, a carrier signal having a carrier number N equal to 5 and X_N equal to [3, 8, 1, 4, 9, 5, . . .] has a phase shift added to the phase characteristic of the carrier signal that is equal to

$$(9) \times \frac{\pi}{6}(\mathrm{mod}2\pi) = \frac{3\pi}{2}(\text{Note that 9 is the } 5^{th} \text{ value in } X_N.)$$

The carrier signal with a carrier number N equal to 6 has a phase shift added to the phase characteristic of the carrier signal equal to

$$(5) \times \frac{\pi}{6}(\mathrm{mod}2\pi) = \frac{5\pi}{6}.$$

It is to be understood that additional and/or different phase shifting techniques can be used by the phase scrambler **66**, and that PS #1, #2, and #3 are merely illustrative examples of the principles of the invention. The DMT transmitter **22** then combines (step **130**) the carrier signals to form the transmission signal **38**. If the transmission signal is not clipped, as described below, the DMT transmitter **22** consequently transmits (step **160**) the transmission signal **38** to the remote receiver **34**.

Clipping of Transmission Signals

A transmission signal **38** that has high peak values of voltage (i.e., a high PAR) can induce non-linear distortion in the DMT transmitter **22** and the communication channel **18**. One form of this non-linear distortion of the transmission signal **38** that may occur is the limitation of the amplitude of the transmission signal **38** (i.e., clipping). For example, a particular DMT symbol **70** clips in the time domain when one or more time domain samples in that DMT symbol **70** are larger than the maximum allowed digital value for the DMT symbols **70**. In multicarrier communication systems when clipping occurs, the transmission signal **38** does not accurately represent the input serial data bit signal **54**.

In one embodiment, the DSL communication system **2** avoids the clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. The DMT transmitter **22** detects (step **140**) the clipping of the transmission signal **38**. If a particular DMT symbol **70** clips in the time domain to produce a clipped transmission signal **38**, the DMT transmitter **22** substitutes (step **150**) a predefined transmission signal **78** for the clipped transmission signal **38**.

The predefined transmission signal **78** has the same duration as a DMT symbol **70** (e.g., 250 ms) in order to maintain symbol timing between the DMT transmitter **22** and the remote receiver **34**. The predefined transmission signal **78** is not based on (i.e., independent of) the modulated input data bit stream **54**; it is a bit value pattern that is recognized by the remote receiver **34** as a substituted signal. In one embodiment, the predefined transmission signal **78** is a known pseudo-random sequence pattern that is easily detected by the remote receiver **34**. In another embodiment, the predefined transmission signal **78** is an "all zeros" signal, which is a zero voltage signal produced at the DMT transmitter **22** output (i.e., zero volts modulated on all the carrier signals). In addition to easy detection by the remote receiver **34**, the zero voltage signal reduces the power consumption of the DMT transmitter **22** when delivered by the DMT transmitter **22**. Further, a pilot tone is included in the predefined transmission signal **78** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the predefined transmission signal **78**.

After the remote receiver **34** receives the transmission signal **38**, the remote receiver **34** determines if the transmission signal **38** is equivalent to the predefined transmission signal **78**. In one embodiment, when the remote receiver **34** identi-

fies the predefined transmission signal **78**, the remote receiver **34** ignores (i.e., discards) the predefined transmission signal **78**.

Following the transmission of the predefined transmission signal **78**, the phase scrambler **66** shifts (step **120**) the phase characteristic of the QAM-modulated carrier signals (based on one of the predefined parameters that varies over time). For example, consider that a set of QAM symbols **58** produces a DMT symbol **70** comprising a plurality of time domain samples, and that one of the time domain samples is larger than the maximum allowed digital value for the DMT symbol **70**. Therefore, because the transmission signal **38** would be clipped when sent to the remote receiver **34**, the DMT transmitter **22** sends the predefined transmission signal **78** instead.

After transmission of the predefined transmission signal **78**, the DMT transmitter **22** again attempts to send the same bit values that produced the clipped transmission signal **38** in a subsequent DMT symbol **70'**. Because the generation of phase shifts in this embodiment is based on values that vary over time, the phase shifts computed for the subsequent DMT symbol **70'** are different than those that were previously computed for the DMT symbol **70** with the clipped time domain sample. These different phase shifts are combined to the phase characteristics of the modulated carrier signals to produce carrier signals of the subsequent DMT symbol **70'** with different phase characteristics than the carrier signals of the DMT symbol **70** with the clipped time domain sample.

DMT communication systems **2** infrequently produce transmission signals **38** that clip (e.g., approximately one clip every 10^7 time domain samples 70). However, if the subsequent DMT symbol **70'** includes a time domain sample that clips, then the predefined transmission signal **78** is again transmitted (step **150**) to the remote receiver **34** instead of the clipped transmission signal **38**. The clipping time domain sample may be on the same or on a different carrier signal than the previously clipped DMT symbol **70**. The DMT transmitter **22** repeats the transmission of the predefined transmission signal **78** until the DMT transmitter **22** produces a subsequent DMT symbol **70'** that is not clipped. When the DMT transmitter **22** produces a DMT symbol **70'** that is not clipped, the DTM transmitter **22** transmits (step **160**) the transmission signal **38** to the remote receiver **34**. The probability of a DMT symbol **70** producing a transmission signal **38** that clips in the time domain depends on the PAR of the transmission signal **38**.

For example, the following phase shifting example, PST #4, illustrates the method used by the phase scrambler **66** to combine a different phase shift to the phase characteristic of each carrier signal to avoid the clipping of the transmission signal **38**.

Phase Shifting Example #4

Phase shifting example #4 (PS #4) corresponds to adjusting the phase characteristic of the carrier signal associated with a carrier number N by

$$\frac{\pi}{3}\times(M+N),$$

mod 2π, where M is the DMT symbol count. In this example, if the DMT symbol **70** clips when the DMT symbol count M equals 5, the predefined transmission signal **78** is transmitted instead of the current clipped transmission signal **38**. On the following DMT symbol period, the DMT count M equals 6, thereby causing a different set of time domain samples to be generated for the subsequent DMT symbol **70'**, although the QAM symbols **58** used to produce both DMT symbols **70**, **70'** are the same.

If this different set of time domain samples (and consequently the transmission signal **38**) is not clipped, the DMT transmitter **22** sends the transmission signal **38**. If one of the time domain samples in the different set of time domain samples 70 (and consequently the transmission signal **38**) is clipped, then the DMT transmitter **22** sends the predefined transmission signal **78** again. The process continues until a DMT symbol **70** is produced without a time domain sample **70** that is clipped. In one embodiment, the transmitter **22** stops attempting to produce a non-clipped DMT symbol **70'** for the particular set of QAM symbols **58** after generating a predetermined number of clipped DMT symbols **70'**. At that moment, the transmitter **22** can transmit the most recently produced clipped DMT symbol **70'** or the predetermined transmission signal **78**.

The PAR of the DSL communication system **2** is reduced because the predefined transmission signal **78** is sent instead of the transmission signal **38** when the DMT symbol **70** clips. For example, a DMT communication system **2** that normally has a clipping probability of 10-7 for the time domain transmission signal **38** can therefore operate with a 10-5 probability of clipping and a lower PAR equal to 12.8 dB (as compared to 14.5 dB). When operating at a 10-5 probability of clipping, assuming a DMT symbol **70** has 512 time-domain samples 70, the DMT transmitter **22** experiences one clipped DMT symbol **70** out of every

$$\frac{10^5}{512},$$

or 195 DMT symbols **70**. This results in the predefined (non-data carrying) transmission signal **78** being transmitted, on average, once every 195 DMT symbols. Although increasing the probability of clipping to 10^{-5} results in approximately a 0.5% (1/195) decrease in throughput, the PAR of the transmission signal **38** is reduced by 1.7 dB, which reduces transmitter complexity in the form of power consumption and component linearity.

While the invention has been shown and described with reference to specific preferred embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the following claims. For example, although the specification uses DSL to describe the invention, it is to be understood that various form of DSL can be used, e.g., ADSL, VDSL, SDSL, HDSL, HDSL2, or SHDSL. It is also to be understood that the principles of the invention apply to various types of applications transported over DSL systems (e.g., telecommuting, video conferencing, high speed Internet access, video-on demand).

What is claimed:

1. In a multicarrier modulation system including a first transceiver in communication with a second transceiver using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits, each carrier signal having a phase characteristic associated with at least one bit of the plurality of data bits, a method for scrambling the phase characteristics of the carrier signals comprising:

transmitting the plurality of data bits from the first transceiver to the second transceiver;

associating a carrier signal with a value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator;

determining a phase shift for the carrier signal at least based on the value associated with the carrier signal;

modulating at least one bit of the plurality of data bits on the carrier signal;

modulating the at least one bit on a second carrier signal of the plurality of carrier signals.

2. The method of claim **1**, wherein one or more of the first transceiver and second transceiver are cable transceivers.

3. The method of claim **1**, wherein one or more of the first transceiver and second transceiver are VDSL transceivers.

4. The method of claim **1**, wherein the first and second transceivers are multicarrier DSL transceivers.

5. The method of claim **1**, wherein the first and second transceivers are used for high speed interne access.

6. The method of claim **1**, further comprising, independently deriving the values associated with each carrier using a second pseudo-random number generator in the second transceiver.

7. The method of claim **6**, further comprising using in the first and second transceivers a same seed for the first and second pseudo-random number generators and the value of the seed is transmitted from the first transceiver to the second transceiver.

8. The method of claim **6**, wherein the first and second transceivers are wireless transceivers.

9. The method of claim **6**, wherein the first and second transceivers are cable transceivers.

10. The method of claim **6**, wherein the first and second transceivers are DSL transceivers connected using a pair of twisted wires of a telephone subscriber system.

11. The method of claim **10**, wherein the first and second transceivers are VDSL transceivers.

12. The method of claim **6**, wherein the first and second transceivers are multicarrier DSL transceivers.

13. The method of claim **6**, wherein the first and second transceivers are also used for transport high speed internet access.

14. The method of claim **1**, wherein the first and the second transceivers include digital signal processors.

15. A multicarrier modulation system including a first transceiver in communication with a second transceiver using a transmission signal having a plurality of carrier signals for modulating a plurality of data bits, each carrier signal having a phase characteristic associated with the input bit stream, the first transceiver capable of transmitting to the second transceiver the plurality of bits and operable to:

associate a carrier signal with a value determined independently of any bit of the plurality of data bits carried by the carrier signal, the value associated with the carrier signal determined by a pseudo-random number generator;

determine a phase shift for the carrier signal at least based on the value associated with the carrier signal;

modulate at least one bit of the plurality of data bits on the carrier signal; and

modulate the at least one bit on a second carrier signal of the plurality of carrier signals.

16. The system of claim **15**, wherein one or more of the first transceiver and second transceiver are cable transceivers.

17. The system of claim **15**, wherein one or more of the first transceiver and second transceiver are VDSL transceivers.

18. The system of claim **15**, wherein the first and second transceivers are multicarrier DSL transceivers.

19. The system of claim **15**, wherein the first and second transceivers are used for high speed internet access.

20. The system of claim **15**, wherein the first transceiver independently derives the values associated with each carrier using a second pseudo-random number generator in the first transceiver.

21. The system of claim **20**, using in the first and second transceivers a same seed for the first and second pseudo-random number generators and the value of the seed is transmitted from the first transceiver to the second transceiver.

22. The system of claim **20**, wherein the first and second transceivers are wireless transceivers.

23. The system of claim **20**, wherein the first and second transceivers are cable transceivers.

24. The system of claim **20**, wherein the first and second transceivers are DSL transceivers connected using a pair of twisted wires of a telephone subscriber system.

25. The system of claim **24**, wherein the first and second transceivers are VDSL transceivers.

26. The system of claim **20**, wherein the first and second transceivers are multicarrier DSL transceivers.

27. The system of claim **20**, wherein the first and second transceivers are also used for high speed internet access.

28. The method of claim **15**, wherein the first and second transceivers each include digital signal processors.

29. The method of claim **1**, wherein the video is video-on demand.

30. The method of claim **15**, wherein the video is video-on demand.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

Page 1 of 1

PATENT NO.	: 8,718,158 B2
APPLICATION NO.	: 13/303417
DATED	: May 6, 2014
INVENTOR(S)	: Marcos C. Tzannes

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 11, Claim 1, line 9, following "signal;" insert -- and --

Column 11, Claim 5, line 19, delete "Interne" and insert -- Internet --

Signed and Sealed this
Sixteenth Day of September, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 8,718,158 B2	Page 1 of 1
APPLICATION NO.	: 13/303417	
DATED	: May 6, 2014	
INVENTOR(S)	: Marcos C. Tzannes	

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

At Column 11, Claim 15, line 49, delete "the input bit stream," and insert -- at least one bit of the plurality of data bits, --

Signed and Sealed this
Twenty-eighth Day of April, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

US009014243B2

(12) **United States Patent**
Tzannes

(10) **Patent No.: US 9,014,243 B2**
(45) **Date of Patent: Apr. 21, 2015**

(54) **SYSTEM AND METHOD FOR SCRAMBLING USING A BIT SCRAMBLER AND A PHASE SCRAMBLER**

(71) Applicant: **TQ Delta, LLC**, Austin, TX (US)

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(73) Assignee: **TQ Delta, LLC**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/718,016**

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(52) **U.S. Cl.**
CPC ***H04L 27/2627*** (2013.01); ***H04L 25/03866*** (2013.01); ***H04L 27/2614*** (2013.01); ***H04L 27/2621*** (2013.01); ***H04B 1/40*** (2013.01)

(58) **Field of Classification Search**
USPC 375/222, 340, 341
See application file for complete search history.

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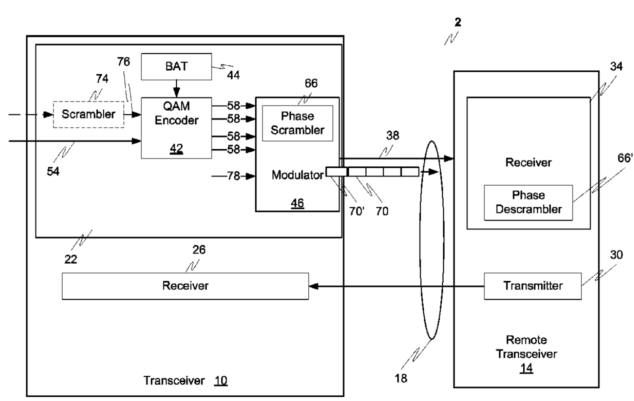
Primary Examiner — Jaison Joseph
(74) *Attorney, Agent, or Firm* — Jason H. Vick; Sheridan Ross, PC

(57) **ABSTRACT**

A system and method that demodulates the phase characteristic of a carrier signal are described. The scrambling of the phase characteristic of each carrier signal includes associating a value with each carrier signal and computing a phase shift for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristic of the carrier signals. Bits of an input signal are modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced PAR.

25 Claims, 2 Drawing Sheets



Related U.S. Application Data

continuation of application No. 11/860,080, filed on Sep. 24, 2007, now Pat. No. 8,073,041, which is a division of application No. 11/211,535, filed on Aug. 26, 2005, now Pat. No. 7,292,627, which is a continuation of application No. 09/710,310, filed on Nov. 9, 2000, now Pat. No. 6,961,369.

(60) Provisional application No. 60/164,134, filed on Nov. 9, 1999.

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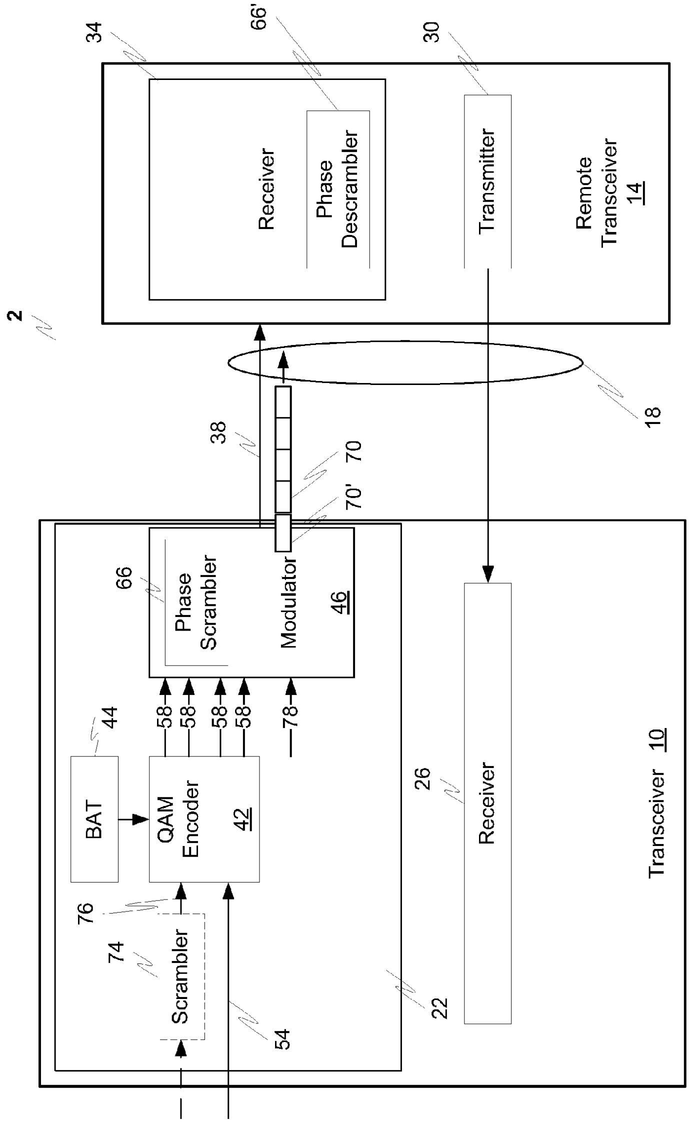

2
Receiver
Phase
Descrambler
Transmitter
Remote
Transceiver
14
34
66'
30
38
18
70
70'
Phase
Scrambler
Modulator
46
66
BAT
QAM
Encoder
42
44
58
58
58
58
78
76
74
Scrambler
54
22
26
Receiver
Transceiver 10

FIG. 1

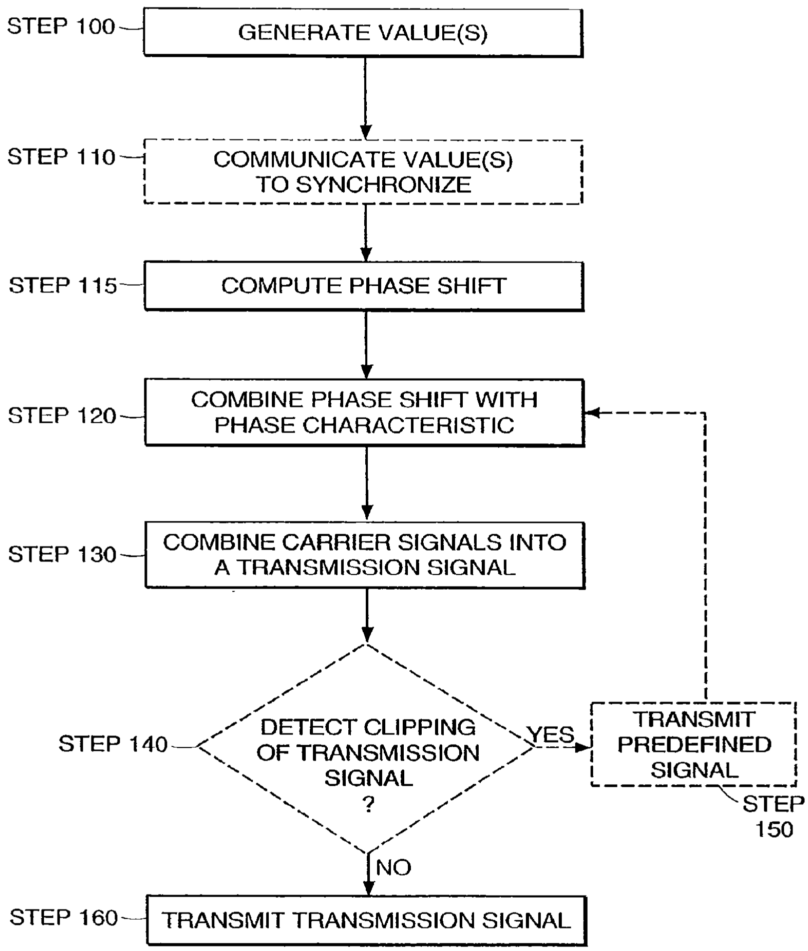

STEP 100
GENERATE VALUE(S)
STEP 110
COMMUNICATE VALUE(S) TO SYNCHRONIZE
STEP 115
COMPUTE PHASE SHIFT
STEP 120
COMBINE PHASE SHIFT WITH PHASE CHARACTERISTIC
STEP 130
COMBINE CARRIER SIGNALS INTO A TRANSMISSION SIGNAL
STEP 140
DETECT CLIPPING OF TRANSMISSION SIGNAL ?
YES
TRANSMIT PREDEFINED SIGNAL
STEP 150
NO
STEP 160
TRANSMIT TRANSMISSION SIGNAL

FIG. 2

SYSTEM AND METHOD FOR SCRAMBLING USING A BIT SCRAMBLER AND A PHASE SCRAMBLER

RELATED APPLICATION

This application is a Continuation of U.S. application Ser. No. 13/439,605, filed Apr. 4, 2012, now U.S. Pat. No. 8,355,427, which is a Continuation of U.S. application Ser. No. 13/284,549, filed Oct. 28, 2011, now U.S. Pat. No. 8,218,610, which is a continuation of Ser. No. 11/860,080, filed Sep. 24, 2007, now U.S. Pat. No. 8,073,041, which is a divisional of U.S. application Ser. No. 11/211,535, filed Aug. 26, 2005, now U.S. Pat. No. 7,292,627, which is a continuation of U.S. application Ser. No. 09/710,310, filed on Nov. 9, 2000, now U.S. Pat. No. 6,961,369, which claims the benefit of the filing date of U.S. Provisional Application Ser. No. 60/164,134, filed Nov. 9, 1999, entitled "A Method For Randomizing The Phase Of The Carriers In A Multicarrier Communications System To Reduce The Peak To Average Power Ratio Of The Transmitted Signal," each which are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

BACKGROUND OF THE INVENTION

In a conventional multicarrier communications system, transmitters communicate over a communication channel using multicarrier modulation or Discrete Multitone Modulation (DMT). Carrier signals (carriers) or sub-channels spaced within a usable frequency band of the communication channel are modulated at a symbol (i.e., block) transmission rate of the system. An input signal, which includes input data bits, is sent to a DMT transmitter, such as a DMT modem. The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals using an Inverse Fast Fourier Transform (IFFT) to generate a time domain signal, or transmission signal, that represents the input signal. The DMT transmitter transmits the transmission signal, which is a linear combination of the multiple carriers, to a DMT receiver over the communication channel.

The phase and amplitude of the carrier signals of DMT transmission signal can be considered random because the phase and amplitude result from the modulation of an arbitrary sequence of input data bits comprising the transmitted information. Therefore, under the condition that the modulated data bit stream is random, the DMT transmission signal can be approximated as having a Gaussian probability distribution. A bit scrambler is often used in the DMT transmitter to scramble the input data bits before the bits are modulated to assure that the transmitted data bits are random and, consequently, that the modulation of those bits produces a DMT transmission signal with a Gaussian probability distribution.

With an appropriate allocation of transmit power levels to the carriers or sub-channels, such a system provides a desirable performance. Further, generating a transmission signal with a Gaussian probability distribution is important in order to transmit a transmission signal with a low peak-to-average ratio (PAR), or peak-to-average power ratio. The PAR of a transmission signal is the ratio of the instantaneous peak value (i.e., maximum magnitude) of a signal parameter (e.g., voltage, current, phase, frequency, power) to the time-averaged value of the signal parameter. In DMT systems, the PAR of the transmitted signal is determined by the probability of the random transmission signal reaching a certain peak voltage during the time interval required for a certain number of symbols. An example of the PAR of a transmission signal transmitted from a DMT transmitter is 14.5 dB, which is equivalent to having a 1E-7 probability of clipping. The PAR of a transmission signal transmitted and received in a DMT communication system is an important consideration in the design of the DMT communication system because the PAR of a signal affects the communication system's total power consumption and component linearity requirements of the system.

If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, multiple carrier signals are used to modulate the same input data bits, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a −90 degree phase characteristic of the DMT carrier signal). An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal. Thus, there remains a need for a system and method that can effectively scramble the phase of the modulated carrier signals in order to provide a low PAR for the transmission signal.

SUMMARY OF THE INVENTION

The present invention features a system and method that scrambles the phase characteristics of the modulated carrier signals in a transmission signal. In one aspect, a value is associated with each carrier signal. A phase shift is computed for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals.

In one embodiment, the input bit stream is modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced peak-to-average power ratio (PAR). The value is derived from a predetermined parameter, such as a random number generator, a carrier number, a DMT symbol count, a superframe count, and a hyperframe count. In another embodiment, a predetermined transmission signal is transmitted when the amplitude of the transmission signal exceeds a certain level.

In another aspect, the invention features a method wherein a value is associated with each carrier signal. The value is determined independently of any input bit value carried by that carrier signal. A phase shift for each carrier signal is computed based on the value associated with that carrier signal. The transmission signal is demodulated using the phase shift computed for each carrier signal.

In another aspect, the invention features a system comprising a phase scrambler that computes a phase shift for each carrier signal based on a value associated with that carrier signal. The phase scrambler also combines the phase shift computed for each carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristic of the carrier signals. In one embodiment, a modulator, in communication with the phase scrambler, modulates

bits of an input signal onto the carrier signals having the substantially scrambled phase characteristics to produce a transmission signal with a reduced PAR.

DESCRIPTION OF THE DRAWINGS

The invention is pointed out with particularity in the appended claims. The advantages of the invention described above, as well as further advantages of the invention, may be better understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a block diagram of an embodiment of a digital subscriber line communications system including a DMT (discrete multitone modulation) transceiver, in communication with a remote transceiver, having a phase scrambler for substantially scrambling the phase characteristics of carrier signals; and

FIG. **2** is a flow diagram of an embodiment of a process for scrambling the phase characteristics of the carrier signals in a transmission signal.

DETAILED DESCRIPTION

FIG. **1** shows a digital subscriber line (DSL) communication system **2** including a discrete multitone (DMT) transceiver **10** in communication with a remote transceiver **14** over a communication channel **18** using a transmission signal **38** having a plurality of carrier signals. The DMT transceiver **10** includes a DMT transmitter **22** and a DMT receiver **26**. The remote transceiver **14** includes a transmitter **30** and a receiver **34**. Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM).

The communication channel **18** provides a downstream transmission path from the DMT transmitter **22** to the remote receiver **34**, and an upstream transmission path from the remote transmitter **30** to the DMT receiver **26**. In one embodiment, the communication channel **18** is a pair of twisted wires of a telephone subscriber line. In other embodiments, the communication channel **18** can be a fiber optic wire, a quad cable, consisting of two pairs of twisted wires, or a quad cable that is one of a star quad cable, a Dieselhorst-Martin quad cable, and the like. In a wireless communication system wherein the transceivers **10**, **14** are wireless modems, the communication channel **18** is the air through which the transmission signal **38** travels between the transceivers **10**, **14**.

By way of example, the DMT transmitter **22** shown in FIG. **1** includes a quadrature amplitude modulation (QAM) encoder **42**, a modulator **46**, a bit allocation table (BAT) **44**, and a phase scrambler **66**. The DMT transmitter **22** can also include a bit scrambler **74**, as described further below. The remote transmitter **30** of the remote transceiver **14** comprises equivalent components as the DMT transmitter **22**. Although this embodiment specifies a detailed description of the DMT transmitter **22**, the inventive concepts apply also to the receivers **34**, **26** which have similar components to that of the DMT transmitter **22**, but perform inverse functions in a reverse order.

The QAM encoder **42** has a single input for receiving an input serial data bit stream **54** and multiple parallel outputs to transmit QAM symbols **58** generated by the QAM encoder **42** from the bit stream **54**. In general, the QAM encoder **42** maps the input serial bit-stream **54** in the time domain into parallel QAM symbols **58** in the frequency domain. In particular, the QAM encoder **42** maps the input serial data bit stream **54** into N parallel quadrature amplitude modulation (QAM) constellation points **58**, or QAM symbols **58**, where N represents the number of carrier signals generated by the modulator **46**. The BAT **44** is in communication with the QAM encoder **42** to specify the number of bits carried by each carrier signal. The QAM symbols **58** represent the amplitude and the phase characteristic of each carrier signal.

The modulator **46** provides functionality associated with the DMT modulation and transforms the QAM symbols **58** into DMT symbols **70** each comprised of a plurality of time-domain samples. The modulator **46** modulates each carrier signal with a different QAM symbol **58**. As a result of this modulation, carrier signals have phase and amplitude characteristics based on the QAM symbol **58** and therefore based on the input-bit stream **54**. In particular, the modulator **46** uses an inverse fast Fourier transform (IFFT) to change the QAM symbols **58** into a transmission signal **38** comprised of a sequence of DMT symbols **70**. The modulator **46** changes the QAM symbols **58** into DMT symbols **70** through modulation of the carrier signals. In another embodiment, the modulator **46** uses the inverse discrete Fourier transform (IDFT) to change the QAM symbols **58** into DMT symbols **70**. In one embodiment, a pilot tone is included in the transmission signal **38** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the transmission signal **38**.

The modulator **46** also includes a phase scrambler **66** that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristic of that carrier signal. Combining phase shifts with phase characteristics, in accordance with the principles of the invention, substantially scrambles the phase characteristics of the carrier signals in the transmission signal **38**. By scrambling the phase characteristics of the carrier signals, the resulting transmission signal **38** has a substantially minimized peak-to-average (PAR) power ratio. The phase scrambler **66** can be part of or external to the modulator **46**. Other embodiments of the phase scrambler **66** include, but are not limited to, a software program that is stored in local memory and is executed on the modulator **46**, a digital signal processor (DSP) capable of performing mathematical functions and algorithms, and the like. The remote receiver **34** similarly includes a phase descrambler **66'** for use when demodulating carrier signals that have had their phase characteristics adjusted by the phase scrambler **66** of the DMT transceiver **10**.

To compute a phase shift for each carrier signal, the phase scrambler **66** associates one or more values with that carrier signal. The phase scrambler **66** determines each value for a carrier signal independently of the QAM symbols **58**, and, therefore, independently of the bit value(s) modulated onto the carrier signal. The actual value(s) that the phase scrambler **66** associates with each carrier signal can be derived from one or more predefined parameters, such as a pseudo-random number generator (pseudo-RNG), a DMT carrier number, a DMT symbol count, a DMT superframe count, a DMT hyperframe count, and the like, as described in more detail below. Irrespective of the technique used to produce each value, the same technique is used by the DMT transmitter **22** and the remote receiver **34** so that the value associated with a given carrier signal is known at both ends of the communication channel **18**.

The phase scrambler **66** then solves a predetermined equation to compute a phase shift for the carrier signal, using the value(s) associated with that carrier signal as input that effects the output of the equation. Any equation suitable for comput-

ing phase shifts can be used to compute the phase shifts. When the equation is independent of the bit values of the input serial bit stream **54**, the computed phase shifts are also independent of such bit values.

In one embodiment (shown in phantom), the DMT transmitter **22** includes a bit scrambler **74**, which receives the input serial bit stream **54** and outputs data bits **76** that are substantially scrambled. The substantially scrambled bits **76** are then passed to the QAM encoder **42**. When the bit scrambler **74** is included in the DMT transmitter **22**, the operation of the phase scrambler **66** further assures that the transmission signal **38** has a Gaussian probability distribution and, therefore, a substantially minimized PAR.

FIG. **2** shows embodiments of a process used by the DMT transmitter **22** for adjusting the phase characteristic of each carrier signal and combining these carrier signals to produce the transmission signal **38**. The DMT transmitter **22** generates (step **100**) a value that is associated with a carrier signal. Because the value is being used to alter the phase characteristics of the carrier signal, both the DMT transmitter **22** and the remote receiver **34** must recognize the value as being associated with the carrier signal. Either the DMT transmitter **22** and the remote receiver **34** independently derive the associated value, or one informs the other of the associated value. For example, in one embodiment the DMT transmitter **22** can derive the value from a pseudo-RNG and then transmit the generated value to the remote receiver **34**. In another embodiment, the remote receiver **34** similarly derives the value from the same pseudo-RNG and the same seed as used by the transmitter (i.e., the transmitter pseudo-RNG produces the same series of random numbers as the receiver pseudo-RNG).

As another example, the DMT transmitter **22** and the remote receiver **34** can each maintain a symbol counter for counting DMT symbols. The DMT transmitter **22** increments its symbol counter upon transmitting a DMT symbol; the remote receiver **34** upon receipt. Thus, when the DMT transmitter **22** and the remote receiver **34** both use the symbol count as a value for computing phase shifts, both the DMT transmitter **22** and remote receiver **34** "know" that the value is associated with a particular DMT symbol and with each carrier signal of that DMT symbol.

Values can also be derived from other types of predefined parameters. For example, if the predefined parameter is the DMT carrier number, then the value associated with a particular carrier signal is the carrier number of that signal within the DMT symbol. The number of a carrier signal represents the location of the frequency of the carrier signal relative to the frequency of other carrier signals within a DMT symbol. For example, in one embodiment the DSL communication system **2** provides 256 carrier signals, each separated by a frequency of 4.3125 kHz and spanning the frequency bandwidth from 0 kHz to 1104 kHz. The DMT transmitter **22** numbers the carrier signals from 0 to 255. Therefore, "DMT carrier number 50" represents the 51st DMT carrier signal which is located at the frequency of 215.625 kHz (i.e., 51×4.3125 kHz).

Again, the DMT transmitter **22** and the remote receiver **34** can know the value that is associated with the carrier signal because both the DMT transmitter **22** and the remote receiver **34** use the same predefined parameter (here, the DMT carrier number) to make the value-carrier signal association. In other embodiments (as exemplified above with the transmitter pseudo-RNG), the DMT transmitter **22** can transmit the value to the remote receiver **34** (or vice versa) over the communication channel **18**.

In other embodiments, other predefined parameters can be used in conjunction with the symbol count. One example of such a predefined parameter is the superframe count that increments by one every 69 DMT symbols. One exemplary implementation that achieves the superframe counter is to perform a modulo **68** operation on the symbol count. As another example, the DMT transmitter **22** can maintain a hyperframe counter for counting hyperframes. An exemplary implementation of the hyperframe count is to perform a modulo 255 operation on the superframe count. Thus, the hyperframe count increments by one each time the superframe count reaches 255.

Accordingly, it is seen that some predefined parameters produce values that vary from carrier signal to carrier signal. For example, when the predefined parameter is the DMT carrier number, values vary based on the frequency of the carrier signal. As another example, the pseudo-RNG generates a new random value for each carrier signal.

Other predefined parameters produce values that vary from DMT symbol **70** to DMT symbol **70**. For example, when the predefined parameter is the symbol count, the superframe count, or hyperframe count, values vary based on the numerical position of the DMT symbol **70** within a sequence of symbols, superframes, or hyperframes. Predefined parameters such as the pseudo-RNG, symbol count, superframe count, and superframe can also be understood to be parameters that vary values over time. Any one or combination of the predefined parameters can provide values for input to the equation that computes a phase shift for a given carrier signal.

In one embodiment, the phase scrambling is used to avoid clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. In this embodiment, the DMT transmitter **22** uses a value based on a predefined parameter that varies over time, such as the symbol count, to compute the phase shift. It is to be understood that other types of predefined parameters that vary the values associated with carrier signals can be used to practice the principles of the invention. As described above, the transceivers **10**, **14** may communicate (step **110**) the values to synchronize their use in modulating and demodulating the carrier signals.

The DMT transmitter **22** then computes (step **115**) the phase shift that is used to adjust the phase characteristic of each carrier signal. The amount of the phase shift combined with the phase characteristic of each QAM-modulated carrier signal depends upon the equation used and the one or more values associated with that carrier signal.

The DMT transmitter **22** then combines (step **120**) the phase shift computed for each carrier signal with the phase characteristic of that carrier signal. By scrambling the phase characteristics of the carrier signals, the phase scrambler **66** reduces (with respect to unscrambled phase characteristics) the combined PAR of the plurality of carrier signals and, consequently, the transmission signal **38**. The following three phase shifting examples, PS #1-PS #3, illustrate methods used by the phase scrambler **66** to combine a computed phase shift to the phase characteristic of each carrier signal.

Phase Shifting Example #1

Phase shifting example #1 (PS #1) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$N\times\frac{\pi}{3},$$

modulo (mod) 2π. In this example, a carrier signal having a carrier number N equal to 50 has a phase shift added to the phase characteristic of that carrier signal equal to

$$50\times\frac{\pi}{3}(\mathrm{mod}2\pi)=\frac{2}{3}\pi.$$

The carrier signal with a carrier number N equal to 51 has a phase shift added to the phase characteristic of that carrier signal equal to

$$51\times\frac{\pi}{3}(\mathrm{mod}2\pi)=\pi.$$

The carrier signal with the carrier number N equal to 0 has no phase shift added to the phase characteristic of that carrier signal.

Phase Shifting Example #2

Phase shifting example #2 (PS #2) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(N+M)\times\frac{\pi}{4},$$

mod 2π, where M is the symbol count. In this example, a carrier signal having a carrier number N equal to 50 on DMT symbol count M equal to 8 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50+8)\times\frac{\pi}{4}(\mathrm{mod}2\pi)=\frac{\pi}{2}.$$

The carrier signal with the same carrier number N equal to 50 on the next DMT symbol count M equal to 9 has a phase shift added to the phase characteristic of that carrier signal equal to

$$(50+9)\times\frac{\pi}{4}(\mathrm{mod}2\pi)=\frac{3\pi}{4}.$$

Phase Shifting Example #3

Phase shifting example #3 (PS #3) corresponds to adjusting the phase characteristic of the QAM-modulated carrier signal associated with a carrier number N by

$$(X_N)\times\frac{\pi}{6},$$

mod 2π, where XN is an array of N pseudo-random numbers. In this example, a carrier signal having a carrier number N equal to 5 and XN equal to [3, 8, 1, 4, 9, 5, . . .] has a phase shift added to the phase characteristic of the carrier signal that is equal to

$$(9)\times\frac{\pi}{6}(\mathrm{mod}2\pi)=\frac{3\pi}{2}$$

(Note that 9 is the 5th value in XN.) The carrier signal with a carrier number N equal to 6 has a phase shift added to the phase characteristic of the carrier signal equal to

$$(5)\times\frac{\pi}{6}(\mathrm{mod}2\pi)=\frac{5\pi}{6}.$$

It is to be understood that additional and/or different phase shifting techniques can be used by the phase scrambler **66**, and that PS #1, #2, and #3 are merely illustrative examples of the principles of the invention. The DMT transmitter **22** then combines (step **130**) the carrier signals to form the transmission signal **38**. If the transmission signal is not clipped, as described below, the DMT transmitter **22** consequently transmits (step **160**) the transmission signal **38** to the remote receiver **34**.

Clipping of Transmission Signals

A transmission signal **38** that has high peak values of voltage (i.e., a high PAR) can induce non-linear distortion in the DMT transmitter **22** and the communication channel **18**. One form of this non-linear distortion of the transmission signal **38** that may occur is the limitation of the amplitude of the transmission signal **38** (i.e., clipping). For example, a particular DMT symbol **70** clips in the time domain when one or more time domain samples in that DMT symbol **70** are larger than the maximum allowed digital value for the DMT symbols **70**. In multicarrier communication systems when clipping occurs, the transmission signal **38** does not accurately represent the input serial data bit signal **54**.

In one embodiment, the DSL communication system **2** avoids the clipping of the transmission signal **38** on a DMT symbol **70** by DMT symbol **70** basis. The DMT transmitter **22** detects (step **140**) the clipping of the transmission signal **38**. If a particular DMT symbol **70** clips in the time domain to produce a clipped transmission signal **38**, the DMT transmitter **22** substitutes (step **150**) a predefined transmission signal **78** for the clipped transmission signal **38**.

The predefined transmission signal **78** has the same duration as a DMT symbol **70** (e.g., 250 ms) in order to maintain symbol timing between the DMT transmitter **22** and the remote receiver **34**. The predefined transmission signal **78** is not based on (i.e., independent of) the modulated input data bit stream **54**; it is a bit value pattern that is recognized by the remote receiver **34** as a substituted signal. In one embodiment, the predefined transmission signal **78** is a known pseudo-random sequence pattern that is easily detected by the remote receiver **34**. In another embodiment, the predefined transmission signal **78** is an "all zeros" signal, which is a zero voltage signal produced at the DMT transmitter **22** output (i.e., zero volts modulated on all the carrier signals). In addition to easy detection by the remote receiver **34**, the zero voltage signal reduces the power consumption of the DMT transmitter **22** when delivered by the DMT transmitter **22**. Further, a pilot tone is included in the predefined transmission signal **78** to provide a reference signal for coherent demodulation of the carrier signals in the remote receiver **34** during reception of the predefined transmission signal **78**.

After the remote receiver **34** receives the transmission signal **38**, the remote receiver **34** determines if the transmission signal **38** is equivalent to the predefined transmission signal **78**. In one embodiment, when the remote receiver **34** identi-

fies the predefined transmission signal **78**, the remote receiver **34** ignores (i.e., discards) the predefined transmission signal **78**.

Following the transmission of the predefined transmission signal **78**, the phase scrambler **66** shifts (step **120**) the phase characteristic of the QAM-modulated carrier signals (based on one of the predefined parameters that varies over time). For example, consider that a set of QAM symbols **58** produces a DMT symbol **70** comprising a plurality of time domain samples, and that one of the time domain samples is larger than the maximum allowed digital value for the DMT symbol **70**. Therefore, because the transmission signal **38** would be clipped when sent to the remote receiver **34**, the DMT transmitter **22** sends the predefined transmission signal **78** instead.

After transmission of the predefined transmission signal **78**, the DMT transmitter **22** again attempts to send the same bit values that produced the clipped transmission signal **38** in a subsequent DMT symbol **70'**. Because the generation of phase shifts in this embodiment is based on values that vary over time, the phase shifts computed for the subsequent DMT symbol **70'** are different than those that were previously computed for the DMT symbol **70** with the clipped time domain sample. These different phase shifts are combined to the phase characteristics of the modulated carrier signals to produce carrier signals of the subsequent DMT symbol **70'** with different phase characteristics than the carrier signals of the DMT symbol **70** with the clipped time domain sample.

DMT communication systems **2** infrequently produce transmission signals **38** that clip (e.g., approximately one clip every 10^7 time domain samples **70**). However, if the subsequent DMT symbol **70'** includes a time domain sample that clips, then the predefined transmission signal **78** is again transmitted (step **150**) to the remote receiver **34** instead of the clipped transmission signal **38**. The clipping time domain sample may be on the same or on a different carrier signal than the previously clipped DMT symbol **70**. The DMT transmitter **22** repeats the transmission of the predefined transmission signal **78** until the DMT transmitter **22** produces a subsequent DMT symbol **70'** that is not clipped. When the DMT transmitter **22** produces a DMT symbol **70'** that is not clipped, the DTM transmitter **22** transmits (step **160**) the transmission signal **38** to the remote receiver **34**. The probability of a DMT symbol **70** producing a transmission signal **38** that clips in the time domain depends on the PAR of the transmission signal **38**.

For example, the following phase shifting example, PST #4, illustrates the method used by the phase scrambler **66** to combine a different phase shift to the phase characteristic of each carrier signal to avoid the clipping of the transmission signal **38**.

Phase Shifting Example #4

Phase shifting example #4 (PS #4) corresponds to adjusting the phase characteristic of the carrier signal associated with a carrier number N by

$$\frac{\pi}{3} \times (M + N),$$

mod 2π, where M is the DMT symbol count. In this example, if the DMT symbol **70** clips when the DMT symbol count M equals 5, the predefined transmission signal **78** is transmitted instead of the current clipped transmission signal **38**. On the following DMT symbol period, the DMT count M equals 6, thereby causing a different set of time domain samples to be generated for the subsequent DMT symbol **70'**, although the QAM symbols **58** used to produce both DMT symbols **70**, **70'** are the same.

If this different set of time domain samples (and consequently the transmission signal **38**) is not clipped, the DMT transmitter **22** sends the transmission signal **38**. If one of the time domain samples in the different set of time domain samples **70** (and consequently the transmission signal **38**) is clipped, then the DMT transmitter **22** sends the predefined transmission signal **78** again. The process continues until a DMT symbol **70** is produced without a time domain sample **70** that is clipped. In one embodiment, the transmitter **22** stops attempting to produce a non-clipped DMT symbol **70'** for the particular set of QAM symbols **58** after generating a predetermined number of clipped DMT symbols **70'**. At that moment, the transmitter **22** can transmit the most recently produced clipped DMT symbol **70'** or the predetermined transmission signal **78**.

The PAR of the DSL communication system **2** is reduced because the predefined transmission signal **78** is sent instead of the transmission signal **38** when the DMT symbol **70** clips. For example, a DMT communication system **2** that normally has a clipping probability of 10-7 for the time domain transmission signal **38** can therefore operate with a 10-5 probability of clipping and a lower PAR equal to 12.8 dB (as compared to 14.5 dB). When operating at a 10-5 probability of clipping, assuming a DMT symbol **70** has 512 time-domain samples **70**, the DMT transmitter **22** experiences one clipped DMT symbol **70** out of every

$$\frac{10^5}{512},$$

or 195 DMT symbols **70**. This results in the predefined (non-data carrying) transmission signal **78** being transmitted, on average, once every 195 DMT symbols.

Although increasing the probability of clipping to 10^{-5} results in approximately a 0.5% 1/195) decrease in throughput, the PAR of the transmission signal **38** is reduced by 1.7 dB, which reduces transmitter complexity in the form of power consumption and component linearity.

While the invention has been shown and described with reference to specific preferred embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the following claims. For example, although the specification uses DSL to describe the invention, it is to be understood that various form of DSL can be used, e.g., ADSL, VDSL, SDSL, HDSL, HDSL2, or SHDSL. It is also to be understood that the principles of the invention apply to various types of applications transported over DSL systems (e.g., telecommuting, video conferencing, high speed Internet access, video-on demand).

What is claimed:

1. A method, in a multicarrier communications transceiver comprising a bit scrambler followed by a phase scrambler, comprising:

scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;

scrambling, using the phase scrambler, a plurality of carrier phases associated with the plurality of scrambled output bits;

transmitting at least one scrambled output bit on a first carrier; and

transmitting the at least one scrambled output bit on a second carrier.

2. The method of claim **1**, wherein the transceiver is a cable transceiver.

3. The method of claim **1**, wherein the transceiver is a DSL transceiver.

4. The method of claim **1**, wherein the transceiver is a wireless transceiver.

5. The method of claim **1**, wherein the transceiver is operable for high speed internet access.

6. The method of claim **1**, wherein the transceiver is operable to transport video.

7. A multicarrier communications transceiver comprising:

a bit scrambler operable to scramble a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;

a phase scrambler operable to scramble a plurality of carrier phases associated with the plurality of scrambled output bits; and

a transmitter portion operable to transmit at least one scrambled output bit on a first carrier and to transmit the at least one scrambled output bit on a second carrier.

8. The transceiver of claim **7**, wherein the transceiver is a cable transceiver.

9. The transceiver of claim **7**, wherein the transceiver is a DSL transceiver.

10. The transceiver of claim **7**, wherein the transceiver is a wireless transceiver.

11. The transceiver of claim **7**, wherein the transceiver is operable for high speed internet access.

12. The transceiver of claim **7**, wherein the transceiver is operable to transport video.

13. A communication device comprising:

a multicarrier transmitter operable to support a bit scrambler and a phase scrambler for transmission of a plurality of input bits, wherein the bit scrambler is operable to scramble the plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit, and wherein the phase scrambler is operable to scramble a plurality of phases associated with the plurality of input bits.

14. The communication device of claim **13**, wherein the multicarrier transmitter is further operable to transmit at least one scrambled output bit on a first carrier and transmit the at least one scrambled output bit on a second carrier.

15. The communication device of claim **14**, wherein the transceiver is a cable transceiver.

16. The communication device of claim **14**, wherein the transceiver is a DSL transceiver.

17. The communication device of claim **14**, wherein the transceiver is a wireless transceiver.

18. The communication device of claim **14**, wherein the communication device is operable for high speed internet access.

19. The communication device of claim **14**, wherein the communication device is operable to transport video.

20. A method comprising:

supporting, in a communication device comprising a multicarrier communications transceiver, a bit scrambler and a phase scrambler for transmission of a plurality of input bits wherein the bit scrambler scrambles the plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit, and wherein the phase scrambler scrambles a plurality of phases associated with the plurality of input bits.

21. The method of claim **20** further comprising:

transmitting at least one scrambled output bit on a first carrier; and

transmitting the at least one scrambled output bit on a second carrier.

22. The method of claim **20**, wherein the transceiver is a DSL transceiver.

23. The method of claim **20**, wherein the transceiver is a wireless transceiver.

24. The method of claim **20**, wherein the communication device is operable for high speed internet access.

25. The method of claim **20**, wherein the communication device is operable to transport video.

* * * * *

"any device that transmits and receives." Ex. 1014, p. 709. Consistent with the specification's description of this term and the dictionary definition, and for the purposes of this proceeding, the broadest reasonable construction of the term "transceiver" includes a "device, such as a modem, with a transmitter and a receiver." Ex. 1009, p. 21.

B. Statutory Grounds for Challenges

Challenge #1: Claims 1-3, 7-9, 13-16, and 20-22 are obvious under 35 U.S.C. § 103(a) over Shively (Ex. 1011) in view of Stopler (Ex. 1012). Shively was filed on December 31, 1997. *See* Ex. 1011. Stopler was filed on February 26, 1999. *See* Ex. 1012. Accordingly, both Shively and Stopler are prior art under § 102(e).

Challenge #2: Claims 4-6, 10-12, 17-19 and 23-25 are obvious under 35 U.S.C. § 103(a) over Shively in view of Stopler, and further in view of Gerszberg (Ex. 1013). Gerszberg was filed on December 31, 1997. *See* Ex. 1013. Accordingly, Gerszberg is prior art under § 102(e).

C. Level of Ordinary Skill in the Art

The level of ordinary skill in the art may be reflected by the prior art of record. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001); *In re GPAC Inc.*, 57 F.3d 1573, 1579 (Fed. Cir. 1995). Here, the person of ordinary skill in the art is someone knowledgeable concerning multicarrier communications.

decode the transmitted bit. Ex. 1011, 16:21-29. Thus, Shively provides a "method for increasing a data rate in a communication channel" by transmitting data on "those parts of the band where transmission would otherwise be impossible." Ex. 1011, 8:2-3 & 16:6-7.

a) Brief Summary of Stopler

Like Shively, Stopler describes multicarrier data transmission, including specifically the use of discrete multitone transmission (DMT). Ex. 1012, 1:50-51. Stopler explains that DMT is one type of multitone modulation, which involves "a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel." Ex. 1012, 1:9-11 & 1:42-45.

Stopler explains that its multitone modulation techniques are compatible with various signal modulation technologies, an example of which employs 256 carriers positioned at different frequencies. Ex. 1012, 1:42-61; 12:55-57. Stopler also explains that its signal transmission scheme may implement techniques of DSL standards such as "ADSL (Asymmetric Digital Subscriber Line)." Ex. 1012, 9:37-41, 12:21-24.

Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26. A POSITA would have understood that the values

transmitted in an overhead channel may not be random, and in fact, may be highly structured. Ex. 1009, p. 24. Without the phase scrambler, the structured nature of the overhead channel could contribute to an increase in the peak-to-average power ratio of the transmitter. Ex. 1009, pp. 24-25.

Stopler is analogous to the ’243 patent because both Stopler and the ’243 patent are in the same field of endeavor – data communications and processing. Ex. 1009 at 25; *see also* Ex. 1012, 1:7-8; Ex. 1001, 1:28-31.

b) Reasons to Combine

It would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely a use of a known technique to improve a similar device, method or product in the same way. Ex. 1009 at 26.

A POSITA would have recognized that by transmitting redundant data on multiple carriers, Shively’s transmitter would suffer from an increased peak-to-average power ratio. Ex. 1009, p. 26. This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. *Id*. When *N* subcarrier signals with the same phase are added together, they have a peak power which is *N* times greater than their individual maximum powers. *Id*.

Since Shively’s subcarriers use quadrature amplitude modulation (QAM)—which encodes bits to be transmitted by modulating the phase and amplitude of the

subcarrier—transmitting the same bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. *Id*. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. *Id*. Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time. *Id*. The '243 patent acknowledges that it was known for a high PAR to result from transmitting the same data on multiple carriers. Ex. 1001, 2:17-21.

Since a high PAR brings numerous disadvantages, a POSITA would have sought out an approach to reduce the PAR of Shively's transmitter. Ex. 1009, p. 27.

Stopler provides a solution for reducing the PAR of a multicarrier transmitter. Specifically, Stopler teaches that a phase scrambler can be employed to randomize the phase of the individual subcarriers. Ex. 1011, 12:24-28. A POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same bits, but without those two subcarriers having the same phase. Ex. 1009, p. 27. Since the two subcarriers are out-of-phase with one another, the subcarriers will not add up coherently at the same time, and thus the peak-to-average power ratio for the overall system will be less than in Shively's original

system. Ex. 1009, p.27-28.

Combining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR. Ex. 1009, p. 28.

Market forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling. As Shively explains, effective use of redundant bit transmission actually *increases* the available bandwidth by exploiting subcarriers that would otherwise be wasted (unused). Combining redundant bit transmission with Stopler's phase scrambling technique would have allowed the development of faster DSL modems *without* requiring more complex (and expensive) circuitry for handling an increased peak-to-average power ratio. Ex. 1009, p. 28.

Thus, it would have been obvious to combine Shively and Stopler as the combination is merely the use of a known technique to improve a similar device, method or product in the same way. *Id*., p. 29.

c) Detailed Claim Analysis

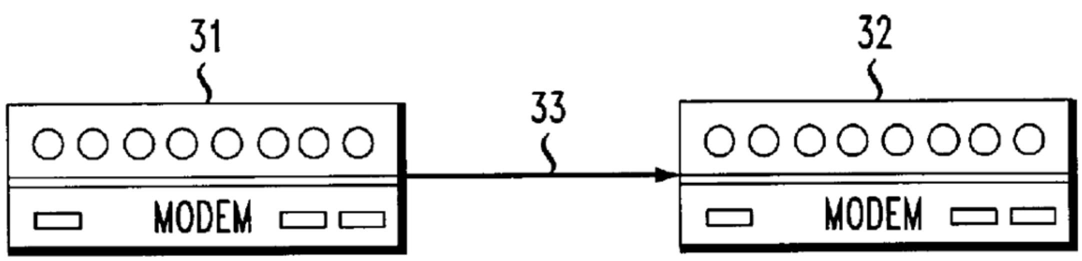
Claim 1

[1.0] "A method, in a multicarrier communications transceiver comprising"

Shively and Stopler each render this limitation obvious. Shively describes a

"method for transmission in a multitone communication system." Ex. 1011, 3:28-29. In connection with Shively's method, it was known to employ multicarrier communications techniques, such as discrete multitone modulation, using a modem. Ex. 1009, p. 29; Ex. 1011, 1:5-7 ("This invention relates to discrete multitone transmission (DMT) of data by digital subscriber loop (DSL) ***modems***."). DMT is an example of a multicarrier modulation system. See Ex. 1001, 1:35-38. As discussed in the claim construction of "transceiver," a modem is an example of a transceiver. Ex. 1009, p. 30.

Shively illustrates in Fig. 2 (below) two communicating modems, where "a transmitting modem 31 . . . [is] connected to a receiving modem 32." Ex. 1011, 9:42, 9:63-64 & Fig. 2. The transmitting modem is a "multicarrier communications transceiver." Ex. 1009, p. 30.



Ex. 1011, Fig. 2.

Similarly, Stopler teaches "a method and apparatus for encoding/framing a data stream of multitone modulated signals." Ex. 1012, 1:7-12. Stopler explains that "<u>[m]ultitone modulation is a signal transmission scheme</u> which uses a <u>number</u>

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Paper No. 7
Filed: November 4, 2016

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020
Patent 9,014,243 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges.*

DESHPANDE, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

I. INTRODUCTION

Cisco Systems, Inc. ("Petitioner") filed a Petition requesting an *inter partes* review of claims 1–25 of U.S. Patent No. 9,014,243 B2 (Ex. 1001, "the '243 patent"). Paper 2 ("Pet."). TQ Delta, LLC ("Patent Owner") filed a corrected Preliminary Response. Paper 6 ("Prelim. Resp."). We have jurisdiction under 35 U.S.C. § 314(a), which provides that an *inter partes* review may not be instituted "unless . . . there is a reasonable likelihood that the petitioner would prevail with respect to at least 1 of the claims challenged in the petition." After considering the Petition, the Preliminary Response, and associated evidence, we conclude that Petitioner has demonstrated a reasonable likelihood that it would prevail in showing the unpatentability of claims 1–25 of the '243 patent. Thus, we authorize institution of an *inter partes* review of claims 1–25 of the '243 patent.

A. Related Proceedings

Petitioner indicates that the '243 patent is the subject of several proceedings. *See* Pet. 1.

B. The '243 Patent (Ex. 1001)

The '243 patent discloses multicarrier communication systems that lower the peak-to-average power ratio (PAR) of transmitted signals. Ex. 1001, 1:26–29. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:36–40. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals. *Id.* at 2:40–43. Figure 1 illustrates the multicarrier communication system and is reproduced below:

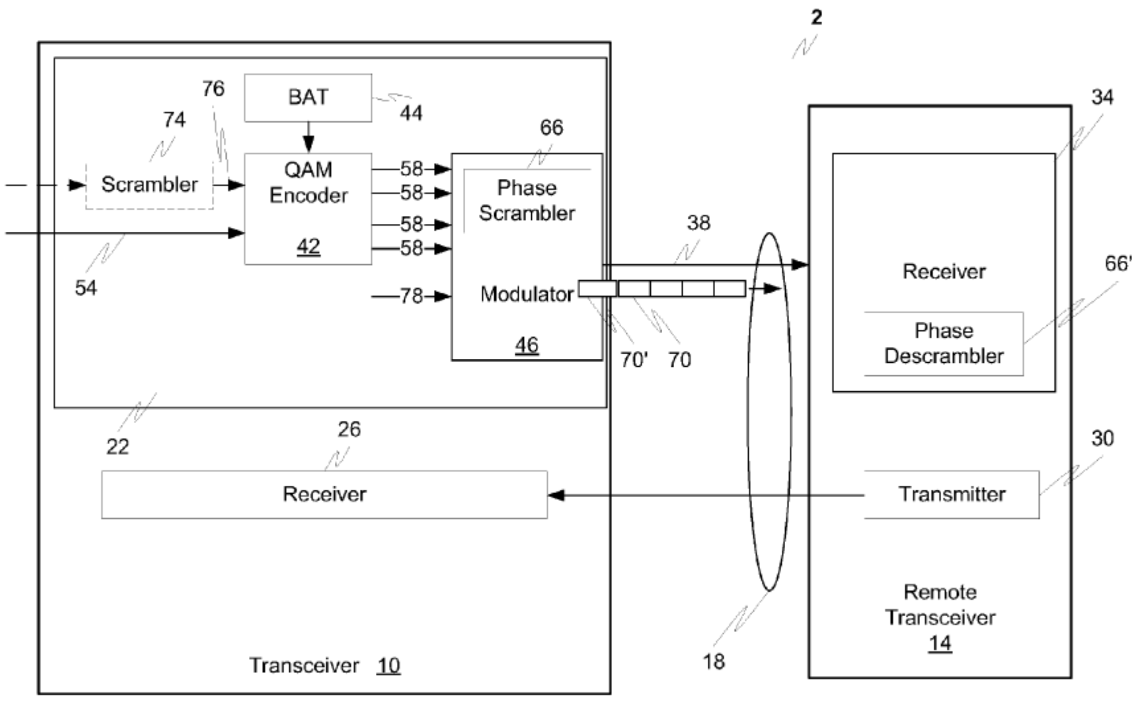

FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2 includes discrete multitoned (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:25–29. DMT transceiver 10 includes DMT transmitter 22 and DMT receiver 26. *Id.* at 3:29–30. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:30–32. DMT transmitter 22 transmits signals over communication channel 8 to receiver 34. *Id.* at 3:38–41.

DMT transmitter 22 includes quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase scrambler 66. QAM encoder 42 has a single input for receiving serial data

bit stream 54 and multiple parallel outputs to transmit QAM symbols 58 generated by QAM encoder 42 from bit stream 54.

Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:10–13. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:13–16. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:29–32.

C. Illustrative Claim

Petitioner challenges claims 1–25 of the ’243 patent. Pet. 8–52. Claims 1, 7, 13, and 20 are independent claims. Claims 2–6 depend from independent claim 1, claims 8–12 depend from independent claim 7, claims 14–19 depend directly or indirectly from independent claim 13, and claims 21–25 depend from independent claim 20. Claim 1 is illustrative of the claims at issue and is reproduced below:

> 1. A method, in a multicarrier communications transceiver comprising a bit scrambler followed by a phase scrambler, comprising:
>
> scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;
>
> scrambling, using the phase scrambler, a plurality of carrier phases associated with the plurality of scrambled output bits;
>
> transmitting at least one scrambled output bit on a first carrier; and

transmitting the at least one scrambled output bit on a second carrier.

Ex. 1001, 10:58–11:4.

D. The Alleged Grounds of Unpatentability

The information presented in the Petition sets forth proposed grounds of unpatentability of claims 1–25 of the ’243 patent under 35 U.S.C. § 103(a) as follows (*see* Pet. 8–52):[1]

References	**Claims Challenged**
Shively[2] and Stopler[3]	1–3, 7–9, 13–16, and 20–22
Shively, Stopler, and Gerszberg[4]	4–6, 10–12, 17–19, and 23–25

II. ANALYSIS

A. Claim Construction

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); *see Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2142–46 (2016). Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the

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[1] Petitioner supports its challenge with the Declaration of Jose Tellado, PhD. (Ex. 1009).
[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) (“Shively”).
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) (“Stopler”).
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) (“Gerszberg”).

context of the entire disclosure. *In re Translogic Tech. Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007).

1. "Multicarrier"

Petitioner argues that the '243 patent specification describes the term "conventional multicarrier communications system" as using a "combination of multiple carriers." Pet. 8 (quoting Ex. 1001, 1:33–47). Accordingly, Petitioner argues that the term "multicarrier" should be construed to encompass "multiple carriers." Patent Owner argues that "[i]t is not necessary at this stage of the proceedings to construe any claim terms." Prelim. Resp. 11–12. On this record, we determine it is not necessary to construe this term for the purposes of this decision.

2. "Transceiver"

Petitioner argues that the'243 patent specification describes that "[t]he DMT transceiver 10 includes a DMT transmitter 22 and a DMT receiver 26." Pet. 8 (quoting Ex. 1001, 3:25–37). Petitioner argues that the '243 patent specification also describes a "transceiver" as a wireless modem, and a technical dictionary defines a "transceiver" as "any device that transmits and receives." *Id.* at 8–9 (citing Ex. 1001, 3:38–50; Ex. 1014, 709). Accordingly, Petitioner argues that a "transceiver" should be construed to mean "a 'device, such as a modem, with a transmitter and a receiver.'" *Id.* (citing Ex. 1009, 21). Patent Owner argues that "[i]t is not necessary at this stage of the proceedings to construe any claim terms." Prelim. Resp. 11–12.

We are persuaded by Petitioner, and, on this record, we interpret "transceiver" to mean "a device, such as a modem, with a transmitter and receiver."

B. Obviousness of Claims 1–3, 7–9, 13–16, and 20–22 over

Shively and Stopler

Petitioner contends that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 10–42. For the reasons discussed below, the evidence, on this record, indicates there is a reasonable likelihood that Petitioner would prevail in showing that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious.

1. Shively (Ex. 1011)

Shively discloses discrete multitoned transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the

corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitoned modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.* at 10:29–30. The serial stream is segmented into N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

2. Stopler (Ex. 1012)

Stopler discloses a method and apparatus for encoding/framing a data stream of multitoned modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67.

3. Analysis

The evidence set forth by Petitioner indicates there is a reasonable likelihood that Petitioner will prevail in showing that claims 1–3, 7–9, 13–16, and 20–22 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 10–42.

For example, the claim 1 preamble recites "[a] method, in a multicarrier communications transceiver comprising a bit scrambler followed by a phase scrambler." Petitioner argues that the combination of Shively and Stopler disclose the preamble. Pet. 15–19. Petitioner argues that Shively discloses a "method for transmission in a multitone communication system," and Shively teaches the use of modems to transmit and receive communications. *Id.* at 15–16 (quoting Ex. 1011, 3:28–29; citing 9:42, 9:63–64, Fig. 2). Petitioner argues that Stopler discloses that "[m]ultitone modulation is a signal transmission scheme which uses a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel" and "[o]ne type of multitone transmission scheme is discrete multitone." *Id.* at 16–17 (quoting Ex. 1012, 1:42–49, 1:50–58; citing Ex. 1009, 31–32) (emphasis omitted). Petitioner further argues that Stopler discloses a transmitter that includes two scramblers, a bit scrambler and a phase scrambler. *Id.* at 18 (citing Ex. 1012, 9:34–37, Fig. 5; Ex. 1009, 33–34).

Claim 1 further recites "scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits." Petitioner argues that Stopler discloses that "data output by the interleaver 54 is rearranged into a serial bit stream (MSB first) and then scrambled in scrambler 56, which is used to randomize the coded and interleaved data." *Id.* at 19 (quoting Ex. 1012, 9:34–48) (emphasis omitted). Petitioner argues that a person with ordinary skill in the art would have recognized that "Stopler's generating a randomizing sequence that is XORed with an input bit stream constitutes 'scrambling . . . a plurality of input bits.'" *Id.* (citing Ex. 1009, 35).

Claim 1 also recites “wherein at least one scrambled output bit is different than a corresponding input bit.” Petitioner argues that Stopler discloses that “the bits of the serial bit stream are ‘scrambled in scrambler 56’ to ‘randomize’ the data.” *Id.* at 20 (citing Ex. 1012, 9:34–47). Petitioner argues that a person with ordinary skill would have recognized that “the XOR operation would result in at least one input bit to be changed when the corresponding bit in the randomizing sequence has a value of 1.” *Id.* at 21 (citing Ex. 1009, 37).

Claim 1 additionally recites “scrambling, using the phase scrambler, a plurality of carrier phases.” Petitioner argues that Stopler discloses that “the phase scrambler applies ‘a phase scrambling sequence’ to ‘data in the form of m-tuples which are to be mapped into QAM symbols.’” *Id.* at 21 (quoting Ex. 1012, 12:20–28). Petitioner argues that Stopler discloses that “the phase scrambled symbol are provided to a modulator that performs signal modulation.” *Id.* at 21–22 (citing Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 39–40). Petitioner further argues that both Shively and Stopler disclose “transmitting information by modulating multiple carrier frequencies.” *Id.* at 22 (citing Ex. 1011, 8:3–13; Ex. 1012, 1:42–49, 1:50–61; Ex. 1009, 40).

Claim 1 further recites “a plurality of carrier phases associated with the plurality of scrambled output bits.” Petitioner argues that the combination of Shively and Stopler discloses that “the plurality of carrier phases are based on the symbols provided to the modulator” and Stopler further discloses “the symbols are mapped from m-tuple data . . . [where] the m-tuple data provided to QAM mapper and phase scrambler 82 are formed by processing the data output by the big scrambler 56 on an ‘upper level’

and a 'lower level.'" *Id.* at 23 (citing Ex. 1012, 9:48–55, 10:1–7, 10:40–11:50, 11:51–54, 12:20–22, Fig. 5; Ex. 1009, 42–43).

Claim 1 also recites "transmitting at least one scrambled output bit on a first carrier" and "transmitting the at least one scrambled output bit on a second carrier." Petitioner argues that Shively discloses determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream in at least a subset of those of the multitone subchannels." *Id.* at 24–25 (quoting Ex. 1011, 8:3–6, 8:5–13). Petitioner further argues that Stopler discloses "transmitting data bits by modulating the data bits on carriers using quadrature amplitude modulation (QAM) and multitoned (multicarrier) modulation." *Id.* at 25 (citing Ex. 1012, 1:42–49, 12:20–28). Petitioner explains that it would have been obvious to a person with ordinary skill in the art "to employ the techniques of Shively and Stopler to transmit at least one scrambled output bit that is provided to the modulator." *Id.* (citing Ex. 1009, 49). Petitioner further argues that Shively discloses transmitting a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 26–27.

Petitioner argues that "[i]t would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely a use of a known technique to improve a similar device, method or product in the same way." *Id.* at 13 (citing Ex. 1009, 26). Petitioner explains that a person of ordinary skill in the art would have recognized that "by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio" because "the overall transmitted

signal in a multicarrier system is essentially the sum of its multiple carriers." *Id.* (citing Ex. 1009, 26). Petitioner asserts that a person of ordinary skill in the art "would have sought out an approach to reduce the [(peak-to-average power ratio)] PAR of Shively's transmitter" and "Stopler provides a solution for reducing the PAR of a multicarrier transmitter." *Id.* at 14 (citing Ex. 1009, 27). Petitioner argues that Stopler discloses "a phase scrambler [that] can be employed to randomize the phase of the individual subcarriers" (*Id.* at 14 (quoting Ex. 1011, 12:24–28)) and "[a] POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same bits, but without those two subcarriers having the same phase." *Id.* at 14. Petitioner explains that "[s]ince the two subcarriers are out-of-phase with one another, the subcarriers will not add up coherently at the same time," thereby reducing the peak-to-average power ratio (PAR) in Shively's system. *Id.* at 14–15. Accordingly, Petitioner argues that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." *Id.* at 15 (citing Ex. 1009, 28).

Patent Owner argues that "no review should be instituted because Petitioner has not provided a sufficient rationale to combine Shively and Stopler." Prelim. Resp. 12. Specifically, Patent Owner argues (1) Shively does not suffer from an increased peak-to-average power ratio (PAR), (2) Shively only uses a small number of carriers and therefore would not suffer from a PAR problem, (3) Stopler is ambiguous as to what it teaches, and (4) Petitioner's rationale for combining Shively and Stopler suffers from hindsight bias. *Id.* at 12–20.

On this record, we are not persuaded by Patent Owner's arguments because Patent Owner's arguments do not rebut the arguments set forth by Petitioner, based on evidence of record. Specifically, Patent Owner set forth attorney argument in substitution for evidence. Petitioner explains, through the testimony of Dr. Tellado, that a person with ordinary skill in the art would have recognized that the combination of Shively and Stopler is nothing more than the use of a known technique to improve a similar device, method or product. Pet. 13 (citing Ex. 1009, 26). Dr. Tellado further explains that a person with ordinary skill in the art would have recognized that Shively would suffer from increased PAR. *Id.* Patent Owner's arguments regarding Shively's lack of increased PAR and Stopler's ambiguity are not persuasive because they are tantamount to attorney arguments not based on any evidence of record. Furthermore, Dr. Tellado discloses that the knowledge of the advantages and benefits of the combination were known at the time of the invention, and, accordingly, we are not persuaded that Petitioner's rationale for combining Shively and Stopler is based on impermissible hindsight. *See* Pet. 13–15; Ex. 1009, 26–28.

C. Obviousness of Claims 4–6, 10–12, 17–19, and 23–25 *over Shively, Stopler, and Gerszberg*

Petitioner contends that claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 42–52. For the reasons discussed below, the evidence, on this record, indicates there is a reasonable likelihood that Petitioner would prevail in showing that claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious.

1. Gerszberg (Ex. 1013)

Gerszberg discloses a telephone network interface unit typically disposed on the outside of a home or small business. Ex. 1013, 1:6–9. An intelligent services director (ISD) is placed near a customer's premises for multiplexing and coordinating many digital services on to a single twisted-pair line. *Id.* at 2:12–23. A facilities management platform (FMP) is placed in the local telephone network's central office for routing data to an appropriate interexchange company network. *Id.* A network server platform (NSP) is coupled to the FMP. *Id.*

2. Analysis

The evidence set forth by Petitioner indicates there is a reasonable likelihood that Petitioner will prevail in showing that claims 4–6, 10–12, 17–19, and 23–25 are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 42–52.

For example, the claim 4 recites "[t]he method of claim 1, wherein the transceiver is a wireless transceiver," claim 5 recites "[t]he method of claim 1, wherein the transceiver is operable for high speed internet access," and claim 6 recites "[t]he method of claim 1, wherein the transceiver is operable to transport video." Petitioner argues that, as discussed above, the combination of Shively and Stopler renders claim 1 obvious. *See* Section II.B.3. Petitioner further argues that Gerszberg discloses the additional limitations of claims 4–6. Pet. 47–49. Petitioner explains that Gerszberg discloses a "transceiver [that] is 'coupled to a central office [] via a twisted-pair wire, hybrid fiber interconnection, wireless and/or other customer connection." *Id.* at 48 (quoting Ex. 1013, 2:67–3:9) (emphasis omitted). Petitioner also argues that Gerszberg discloses "'[h]igh-speed access to the

Internet' and the 'ability to offer ultra fast Internet access.'" *Id.* (quoting Ex. 1013, 7:44–60, 8:16–24). Petitioner additionally argues that Gerszberg discloses "transporting 'video' and providing '[i]nteractive video teleconferencing.'" *Id.*at 49 (quoting Ex. 1013, 8:16–36, 10:63–11:3).

Petitioner further argues that a person with ordinary skill in the art would have combined Gerszberg with Shively/Stopler "because Shively explicitly refers to Gerszberg and incorporates Gerszberg by reference." *Id.* at 43–44 (citing Ex. 1011, 18:7–9; Ex. 1013, 16:52–53; Ex. 1009, 69; *Telemac Cellular Corp. v. Topp Telecom, Inc.*, 247 F.3d 1316, 1329 (Fed. Cir. 2001) (holding "[w]hen a document is 'incorporated by reference' into a host document, such as a patent, the referenced document becomes effectively part of the host document as if it were explicitly contained therein.")). Petitioner alternatively argues that "it would have been obvious to combine the teachings of Gerszberg with Shively and Stopler because the combination is merely the use of a known technique to improve a similar device, method or product in the same way." *Id.* at 44 (citing Ex. 1009, 69). Petitioner explains that both Shively and Stopler "describe transmitting data using DSL and multitone communication technologies" and a person with ordinary skill in the art would have recognized that DSL "was intended to provide data services such as high-speed internet and video to telephone subscribers." *Id.* (citing Ex. 1011, 1:5–8; Ex. 1012, 1:50–61, 90:37–41, 12:21–24, 12:55–57; Ex. 1009, 69). Petitioner argues that it was known that "Service Systems" that are offered by DSL technologies include "Internet access," "Interactive video," and "Videoconferenc[ing]." *Id.* at 44–45 (citing Ex. 1015, 100, 102, 104, Fig. 1). Accordingly, Petitioner argues that the "known technique for providing Internet and video services, as disclosed

by Gerszberg, would be applied to the combination of Shively and Stopler to provide the advantage of addressing the market need for such services." *Id.* at 46 (citing Ex. 1013, 7:44–60, 8:16–36, 10:63–11:3).

Patent Owner argues that this ground relies on Shively and Stopler and "no review should be instituted because Petitioner has not provided a sufficient rationale to combine Shively and Stopler." Prelim. Resp. 12. We have already address this argument above, and, for the same reasons discussed above, are not persuaded. *See* Section II.B.3.

D. Conclusion

For the foregoing reasons, we are persuaded that Petitioner has met its burden of showing a reasonable likelihood that claims 1–25 of the '243 patent are unpatentable.

III. ORDER

After due consideration of the record before us, and for the foregoing reasons, it is:

ORDERED that pursuant to 35 U.S.C. § 314, an *inter partes* review is hereby instituted as to the following grounds:

1. claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent as unpatentable under 35 U.S.C. § 103(a) over Shively and Stopler;
2. claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent as unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and Gerszberg;

FURTHER ORDERED that no other grounds are instituted; and

FURTHER ORDERED that pursuant to 35 U.S.C. § 314(a), *inter partes* review of the '243 patent is hereby instituted commencing on the

entry date of this Order, and pursuant to 35 U.S.C. § 314(c) and 37 C.F.R. § 42.4, notice is hereby given of the institution of a trial.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC. and DISH NETWORK, LLC
Petitioners

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020
Patent No. 9,014,243

PATENT OWNER RESPONSE UNDER 37 CFR § 42.120

TABLE OF CONTENTS

I. INTRODUCTION

Patent Owner TQ Delta, LLC submits this Patent Owner Response under 37 CFR §42.120 to the Petition filed by Cisco, Inc. requesting *inter partes* review for claims 1–25 of U.S. Pat. No. 9,014,243 ("the '243 patent").

The Board instituted *inter partes* review on two grounds:

1. whether claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over U.S. Pat. No. 6,144,696 ("Shively") and U.S. Pat. No. 6,625,219 ("Stopler"); and

2. whether claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and U.S. Pat. No. 6,424,646 ("Gerszberg").

After institution, additional parties—including: Dish Network, LLC; Comcast Cable Communications, LLC; Cox Communications, Inc.; Time Warner Cable Enterprises LLC; Verizon Services Corp.; and ARRIS Group, Inc.—filed petitions that are identical in all substantive respects to the Cisco Petition. *See* IPR2017-00254 and IPR2017-00418. These additional parties moved to join as petitioners, and collectively with Cisco, are referred to herein as "Petitioners." For brevity, this Patent Owner response will cite only to the Cisco Petition and its corresponding exhibits.

In the Institution Decision, the Board did not reach the merits of Patent Owner's arguments in the Patent Owner Preliminary Response, but rather

characterized them as "attorney argument" and accepted Petitioners' expert declarant's testimony as true because Patent Owner did not support it's argument with expert testimony. This Patent Owner Response is fully supported by the cited evidence, including the declaration of Dr. Robert T. Short.

The Petition fails to prove, by a preponderance of the evidence, that any claim of the '243 patent is unpatentable because there is no credible or accurate evidence demonstrating why one having ordinary skill in the art would have combined Shively and Stopler. Petitioners' rationale for the combination fundamentally relies on the contention that Shively suffers from a problem (*i.e.*, a problem with its "peak-to-average power ratio" or "PAR") that Stopler solves the purported problem by performing "phase scrambling." But, Shively does not have a PAR problem so there would have been no motivation to look for a solution.

Furthermore, Stopler does not disclose phase scrambling as recited in the claims.

Petitioners misunderstand the teachings of these references, make unsupported assumptions having no basis in fact, and, ultimately rely on only hindsight bias to cobble together the references.

As such, Petitioners' grounds for alleged obviousness fail. Patent Owner respectfully requests that the Board issue a Final Written Decision finding that Petitioners did not meet their burden to prove unpatentability of claims 1–25 of the

’243 patent.

II. INTRODUCTION TO TECHNOLOGICAL CONCEPTS

In order to understand the issues at hand in this IPR, it is first necessary to be able to answer the following questions:

1) What is a multicarrier system?

2) What is peak-to-average power ratio, or “PAR”?

3) Under what conditions does a PAR “problem” occur?

4) How are the terms “symbol” and “carrier” used in this Patent Owner Response and accompanying declaration?

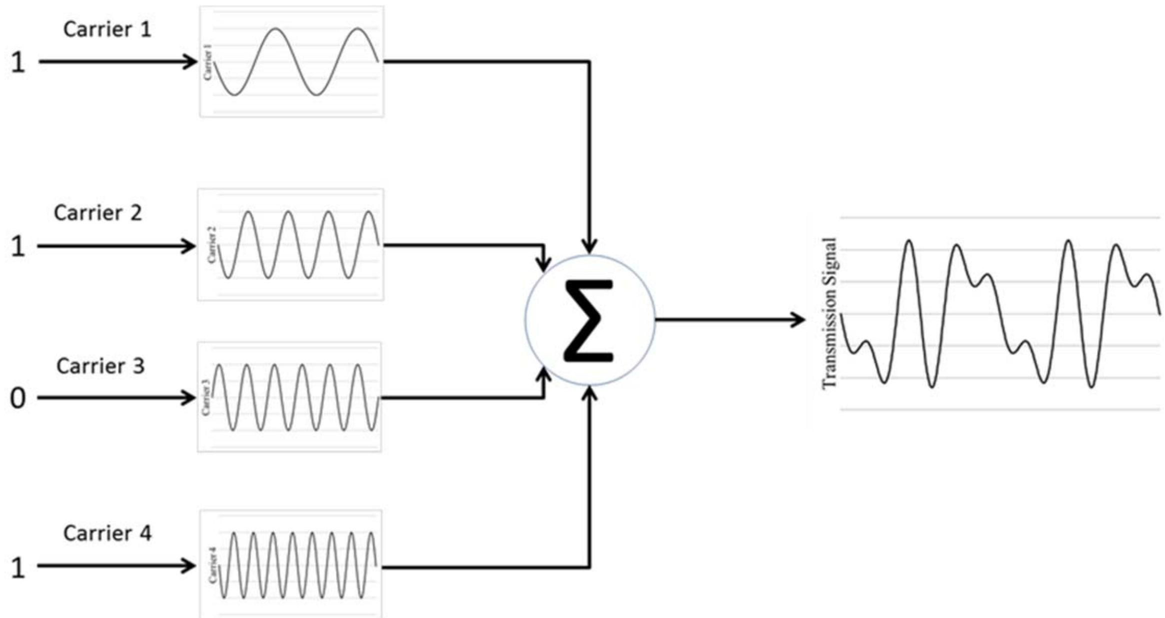
This introduction answers these questions.

A. Multicarrier Systems

The ’243 patent discloses a system that communicates using multicarrier signals. Ex. 1001 at 1:26–29. A multicarrier signal includes a number of carrier signals (or carriers) each operating at a different frequency. Each carrier is modulated to encode one or more bits (*i.e.*, “1” or “0”). Each carrier effectively serves as a separate sub-channel for carrying data. The carriers are combined as a group to produce a transmission signal, which is transmitted across a transmission medium (*e.g.*, phone lines, coaxial cable, the air, *etc.*) to a receiver. *See* Ex. 2003 at ¶ 17.

In an example illustrated below, four carriers—Carrier 1, Carrier 2, Carrier

3, and Carrier 4—are combined simultaneously into one transmission signal.



See Ex. 2003 at ¶ 18.

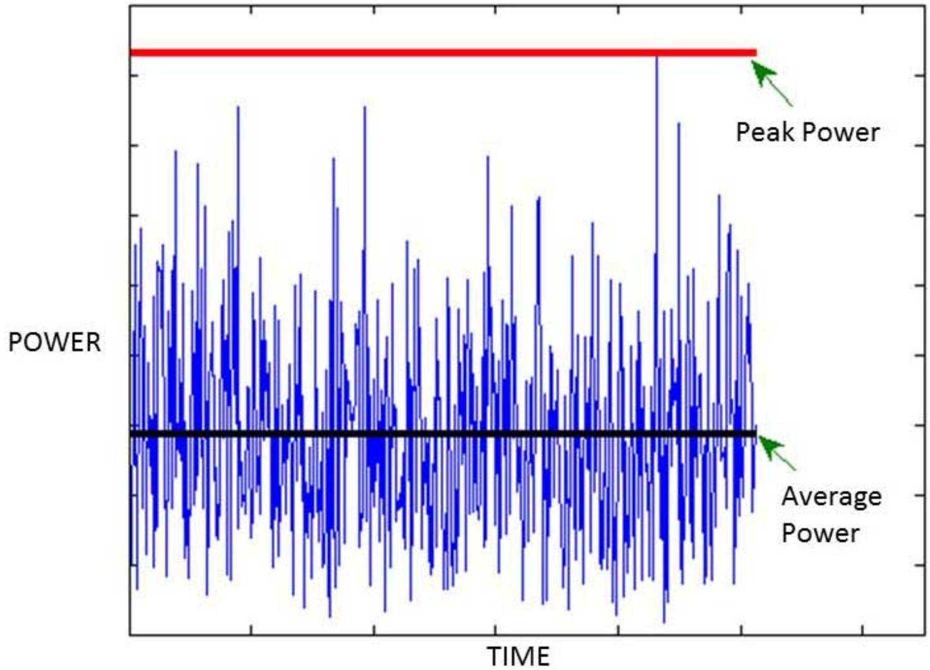
Multicarrier systems may use the phase of carriers to encode different bit values. In the example illustrated above, a carrier with a phase of zero represents a bit value of "0"; conversely, a carrier with a phase-shift of π (or 180°) represents a bit value of "1". In this example, Carriers 1, 2, and 4 have a phase-shift of π, and therefore each represent a "1". Carrier 3 has as phase of zero, and therefore represents a "0". Together, these four carriers encode input bits having binary values of 1, 1, 0, and 1. This information is transmitted as a single transmission signal—that is, the irregular waveform shown above on the right side of the figure. In practice, a multicarrier transmission signal will typically comprise a combination of many more than four carriers (*e.g.*, hundreds or even thousands of

carriers) and in this way can substantially increase the "speed" or data carrying capacity of the system. *See* Ex. 2003 at ¶ 19.

B. Peak-to-Average Power Ratio ("PAR")

A multicarrier transmission signal can be characterized by a metric known as "PAR," which stands for peak-to-average ratio or peak-to-average power ratio. Ex. 1001 at 1:60–65. As the '243 patent explains, "The PAR of a transmission signal is the ratio of the instantaneous peak value (*i.e.*, maximum magnitude) of a signal parameter (*e.g.*, voltage, current, phase, frequency, ***power***) to the time-average value of the signal parameter." *Id.* at 1:65–2:2 (emphasis added). References to PAR herein relate to PAR for the power of a transmission signal. *See* Ex. 2003 at ¶ 20.

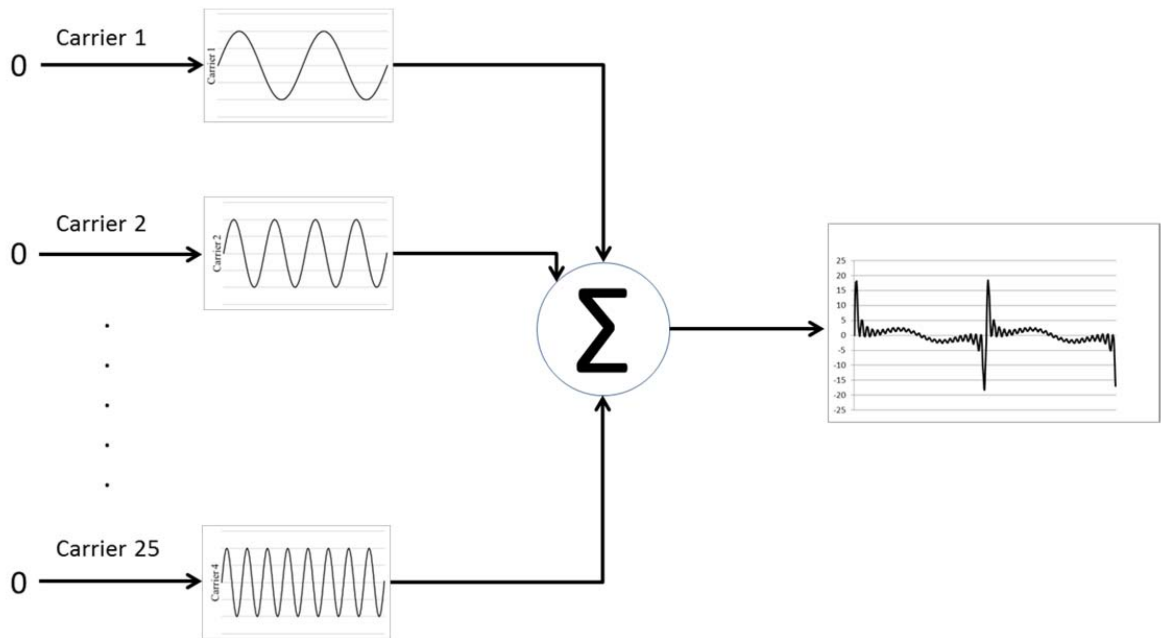
One of the central issues in this IPR relates to PAR. In the following illustration, a signal (blue) has a peak power (red line) and an average power (black line). The ratio of the peak power to the average power of the signal is the PAR.



See Ex. 2003 at ¶ 21.

A high PAR can occur when a large number (or percentage) of the carriers have the same phase. The ’243 patent recognized that: “If the phase of the modulated carriers [in a transmission signal] is not random, then the PAR can increase greatly.” Ex. 1001 at 2:15–16. The phases of the carriers would not be “random,” for example, when the underlying data being modulated is repetitive (*e.g.*, a long string of 0s or a long string of 1s), or where the same bit or bits is/are purposely sent in a redundant manner on multiple carriers. In the example below, all 25 of the carriers have the same phase of zero (which would be the case if the same bit or bits was/were sent on every carrier). Because the carrier signals are “in-phase,” their amplitudes will add together to create a transmission signal

(illustrated on the right side of the figure below) having large spikes in amplitude and, therefore, a high PAR.



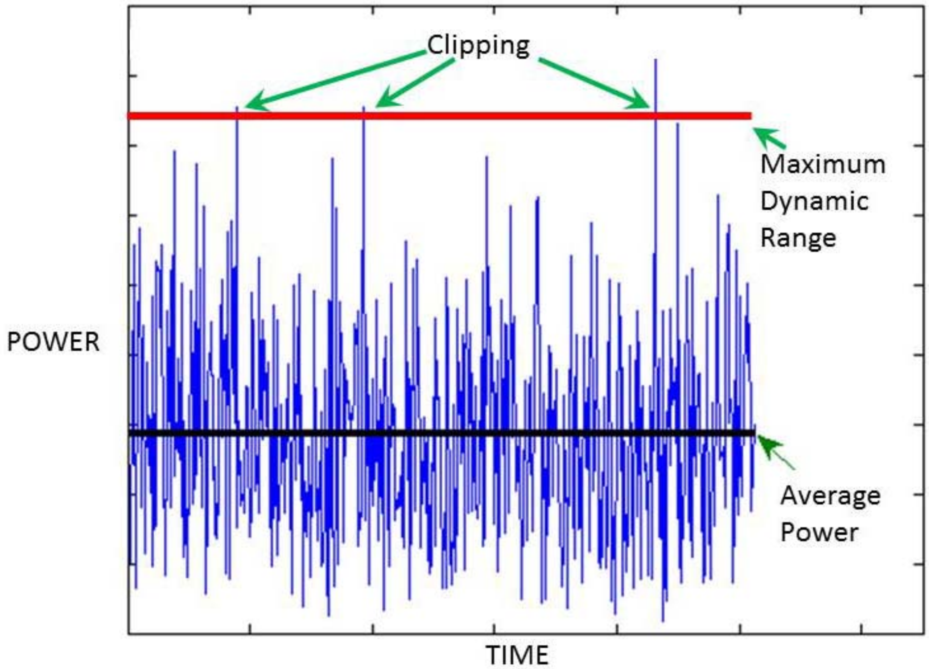
See Ex. 2003 at ¶ 22.

C. PAR "Problem"

Because a multicarrier transmission signal is the sum of many carrier signals, the transmission signal is expected to have a significant PAR. Conventional multicarrier systems, therefore, were designed to accommodate a degree PAR. There is only a PAR "problem," however, when an undue amount of PAR-induced errors occur in a multicarrier transmitter. *See* Ex. 2003 at ¶ 23.

Electronic components in a multicarrier transceiver are ideally designed to process multicarrier signals without distortion. Distortion occurs when a signal exceeds the capacity (or dynamic range) of an electronic component, such as an

amplifier, a digital-to-analog converter, or an analog-to-digital converter. When the maximum dynamic range of a component is exceeded, the signal will become distorted or will "clip."



See Ex. 2003 at ¶ 24.

As a result of clipping, the portion of the signal exceeding the component's dynamic range is truncated and the information in the cut off signal portion is lost. *See* Ex. 2003 at ¶ 25.

One way to reduce the probability of clipping is to use transceiver components with larger dynamic ranges. Such components, however, can be expensive and may consume a relatively large amount of power. Increasing the dynamic ranges of the components to eliminate any possibility of clipping,

therefore, can be impractical. *See* Ex. 2003 at ¶ 26.

Instead of demanding ideal circuitry, multicarrier systems are designed to actually allow a certain amount of clipping. This design criterion is specified as a "clipping rate." One such multicarrier system is digital subscriber line ("DSL").[1] In DSL at the time of the invention (referred to herein as "ADSL-1995") the maximum allowable clipping rate is one in every 10^7 (ten million) samples, which corresponds to a clipping probability of 10^{-7} (or one in ten million). Ex. 1017 at p. 48, § 6.11.1. This exact clipping probability is also referenced in the '243 patent. *See* Ex. 1001 at 2:6–8. *See* Ex. 2003 at ¶ 27.

In ADSL-1995, the ideal sampling rate is approximately 2.2 million samples/second. Given this sampling rate and a clipping probability of 10^{-7}, there would be a clipping error when processing a transmission signal about once every

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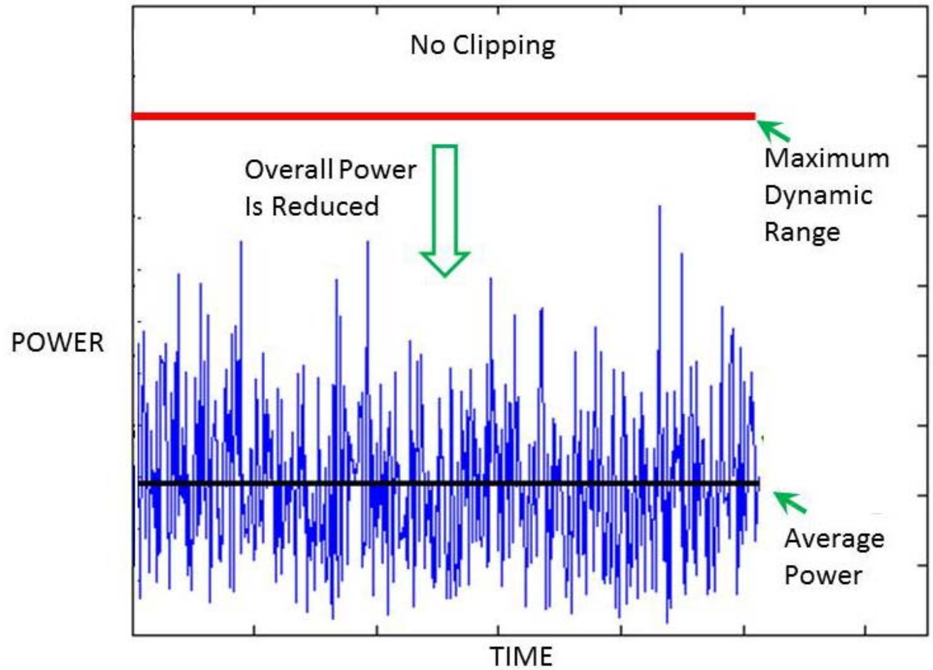
[1] This is an apt example, as DSL is the subject technology of a preferred embodiment in the '243 patent (Ex. 1001 at 3:25–26), Shively (Ex. 1011 at 1:4–5), Stopler (Ex. 1012 at 12: 23–24), and Gerszberg (Ex. 1013 at 1:19–26). A particular DSL standard in use at the time of the invention is defined in Petitioners' Exhibit 1017—ANSI standard T1.413-1995 ("ADSL-1995"). The ADSL-1995 standard is described in Shively (Ex. 1011 at 1:51–53 and 2:12–24) and is discussed in the Petition at p. 46. *See* Ex. 2003 at ¶ 28.

4.55 seconds on average. This clipping rate is deemed acceptable because, at this rate, error correction methods are capable of fixing the errors cause by clipping. *See* Ex. 2003 at ¶ 29.

A PAR "problem" exists when the probability of clipping or average clipping rate exceeds the maximum allowable rate. In the example above, if there is a clipping error once every 3 seconds (on average), then a PAR problem exists—because the rate of clipping is unacceptably high since 3 seconds is less than 4.55 seconds. As the inventor of the '243 patent recognized, "If the phase of the modulated carriers is not random, then the PAR can increase greatly." Ex. 1001 at 2:15–16. "An increased PAR can result in a system with high power consumption and/or with ***high probability of clipping the transmission signal***." *Id.* at 2:25–27 (emphasis added). Contrarily, if probability of clipping or average clipping rate does not increase above the acceptable rate of the system (*e.g.*, 10^{-7} or once every 4.55 seconds on average in ADSL-1995), then there is no PAR problem. *See* Ex. 2003 at ¶ 30.

One way to decrease the impact of PAR and reduce the probability of clipping is by reducing the overall signal power below the maximum overall signal power for which the system was designed, as depicted below.



See Ex. 2003 at ¶ 31.

As discussed below in § IV.A, the system disclosed in Shively is an example of a system in which the overall signal power is reduced below the maximum overall signal power for which the system was designed. Such power reduction is shown by Shively, and it results in a system with virtually no clipping at all. *See* Ex. 2003 at ¶ 32.

D. A Note On Terminology

There is some overlap and apparent inconsistency with certain terminology used by Petitioners and the references of record. Particularly confusing is the use of "symbol." Generally, "symbol" can have two meanings. First, "symbol" can refer to information transmitted on one carrier during a predefined time period (*i.e.*,

a "symbol period"). Second, "symbol" can refer to all of the information transmitted on all of the carriers in a symbol period. The individual carrier symbols are often referred to as "QAM symbols," where "QAM" (Quatrature Amplitude Modulation) is a commonly-used type of modulation used to modulate a carrier symbol onto a carrier. A multicarrier "symbol" (*i.e.*, the collection of multiple carrier symbols) is often referred to as a "DMT symbol," where "DMT" (Discrete Multitone) is a type of multicarrier technology. *See* Ex. 2003 at ¶ 33.

In order to keep things clear and to avoid apparent inconsistency/overlap with the term "symbol," this Patent Owner Response and accompanying declaration employ the terms "carrier" and "symbol" as follows:

- "carrier" means a carrier symbol (*e.g.*, a QAM symbol); and
- "symbol" means a collective multicarrier symbol in a single symbol period (*e.g.*, a DMT symbol).

See Ex. 2003 at ¶ 34. This Patent Owner Response and accompanying declaration also use appropriate editorializing to distinguish between a "carrier" and a "symbol" in the references of record, the Petition, and Petitioners' expert's declaration. *See id.* at ¶ 35.

Further adding to potential confusion is that the terms "carrier," "subcarrier," "band," "sub-band," "bin," "channel," and "tone" are often used interchangeably. Ex. 1011 at 1:42–43 ("sub-bands or frequency bins"); *id*. at 1:48

(“sub-band channels”); *id*. at 5:13–15 (“carrier”); *id*. at 10:40–41 (“subcarriers”); *id*. at 12:39 (“bin (channel)”); Ex. 1012 at 1:41 (“tones or bands”). For consistency, Patent Owner has used the term “carrier” as much as possible in this Patent Owner Response and accompanying declaration. *See* Ex. 2003 at ¶ 36.

III. CLAIM CONSTRUCTION

Petitioners proposed to construe two claim terms: “multicarrier” and “transceiver.” Patent Owner maintains that it is not necessary to construe either of these terms to resolve the issues at hand.

Additionally, Patent Owner proposes to construe “scramble…a plurality of carrier phases” to mean “scramble a plurality of carrier phases in a single multicarrier symbol.”

A. “Multicarrier”

With respect to “multicarrier,” the Board agreed with Patent Owner that there is no need to construe this term for the purposes of the institution decision.

B. “Transceiver”

While the Board opted to construe “transceiver,” Patent Owner maintains that a construction is not necessary to evaluate the grounds of unpatentability presented by the Petitioners. The Board adopted Petitioners’ proposal, namely that a “transceiver” is “a device, such as a modem, with a transmitter and a receiver.” Institution Decision, Paper No. 7 at p. 6. In a corresponding district court matter,

Patent Owner proposed to construe "transceiver" to mean "a communications device capable of transmitting and receiving data over the same physical medium wherein the transmitting and receiving functions are implemented using at least some common circuitry." Ex. 2007 at p. 8. The district court construed "transceiver" to mean "a communications device capable of transmitting and receiving data wherein the transmitter portion and receiver portion share at least some common circuitry." *See id.* at pp. 8–9. Petitioners' arguments fail irrespective of which of the foregoing constructions for "transceiver" is used.

C. "Scrambling…a Plurality of Carrier Phases"

In the context of the '243 patent, "scrambl[e/ing]…a plurality of carrier phases"—or the variant "scramble…a plurality of phases"—should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." This construction is fully supported by the specification of the '243 patent, and it clarifies that the claimed phase scrambling must be performed amongst the individual carrier phases in a single multicarrier symbol. In other words, the claimed phase scrambling is not met if the phase adjustment only occurs over time from one symbol to the next. *See* Ex. 2003 at ¶ 37.

The '243 patent is directed exclusively to multicarrier modulation systems. *See* Ex. 1001 at 1:26–29 ("This invention relates to communications systems using

multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals."); 3:32–37 ("Although described with respect to discrete multitone modulation, the principles of the invention apply also to other types of multicarrier modulation, such as, but not limited to, orthogonally multiplexed quadrature amplitude modulation (OQAM), discrete wavelet multitone (DWMT) modulation, and orthogonal frequency division multiplexing (OFDM)."). Furthermore, every independent claim is directed to a "multicarrier communications transceiver" (claims 1, 7, and 20) or a "multicarrier transmitter" (claim 13). The '243 patent discloses several multicarrier techniques and uses "discrete multitone modulation" ("DMT") as an example. *Id*. at 3:32–37. *See* Ex. 2003 at ¶ 38.

As discussed above in § II.A, a multicarrier signal includes the combination of a plurality of carriers, where each carrier has a different frequency and its own phase. In the embodiment of the '243 patent, each of the plurality of carriers corresponds to a different QAM symbol. *See, e.g.,* Ex. 1001 at 4:13–14 ("The modulator 46 modulates each carrier signal with a different QAM symbol 58."). Each carrier (or QAM symbol) has its own phase or phase characteristic.[2] *See*,

[2] The term "phase characteristic" in the '243 patent is interchangeable with

e.g., *id.* at 4:7–9 ("The QAM symbols 58 represent the amplitude and the phase characteristic of each carrier signal."). The combination of these carriers (or QAM symbols) is referred to as a DMT symbol (which is an exemplary type of multicarrier symbol). *See, e.g.*, *id.* at 9:8–9 ("…a set of QAM symbols 58 produces a DMT symbol 70…."). *See* Ex. 2003 at ¶ 39.

The '243 patent repeatedly discloses a "phase scrambler" that scrambles the phases or phase characteristics of carriers within a single DMT symbol. *See* Ex. 1001 at 6:52–8:13. As the '243 patent explains, PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. *See, id.*, at 6:30–53. If the carrier phases were only adjusted from one symbol to the next, PAR would not be reduced. *See* Ex. 2003 at ¶¶ 41–42.

In a corresponding district court matter, the court construed "scrambling the phase characteristics of the carrier signals" to mean "adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts." Ex. 2007 at pp. 10–11. During prosecution of the '243 patent, the applicant explained that a "scrambler" operates "by pseudo-randomly selecting bits to invert." Ex.

"phase." *See* Ex. 1001 at 1:40–42 ("The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals…."). *See* Ex. 2003 at ¶ 40.

2008 at p. 18. There was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristics of a carrier signal by pseudo-randomly varying amounts. Ex. 2007 at pp. 10–11.

Furthermore, when Petitioners' expert was asked about his application of the claims to the asserted Stopler reference, he expressed his opinion that the claims require phase scrambling within a single multicarrier symbol. In his declaration, he contends that the claims are invalid over a combination of at least Shively and Stopler. Ex. 1009 at ¶¶ 54 and 72. Pertinently, he alleges that Stopler discloses the claim recitations of "scramble…a plurality of carrier phases" and "scramble…a plurality of phases." *Id.* at p. 38–42 (element "1.4a") and p. 61 (element "13.4a").

During cross-examination, Petitioners' expert discussed his opinion that Stopler discloses scrambling within a single multicarrier symbol. Indeed, he specifically rejected that Stopler's phase scrambling could be performed from one multicarrier symbol to the next. Note, in the transcript excerpt below, a "DMT symbol" refers to a single multicarrier symbol, while a "QAM symbol" refers to a single carrier in the DMT (or multicarrier) symbol.

> Q. But you didn't take into consideration when you interpreted that [section of Stopler], that it may be talking about randomizing overhead channels from [one] DMT symbol to the next, did you?
>
> A. The natural interpretation, since Stopler is teaching how to randomize plural overhead channel symbols [*i.e.*, "carriers"], the natural interpretation is that each symbol [*i.e.*, "carrier"] would have a different phase rotation.

> ***Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation?***
>
> ***A. No. No. Individual QAM symbols [i.e., "carrier"] within the same modulation block [i.e., "symbol"].***
>
> Q. Where does it say that?
>
> A. If you read the paragraph, "The input to the QAM mapper 82"—we're on column 12, line 21. "The input to the QAM mapper 82 is data in the form of m-tuples which are to be mapped into QAM symbols"—basically getting m-tuples, mapping them to one QAM symbol—"for example, ranging from QPSK to 256-QAM tone by tone." So in the context of QAM mapper 82, which is in Figure 5, this block is processing at the QAM symbol by the QAM symbol, so each QAM symbol is processed individually. The constellation mapping may be the same as that used in ADSL. So again, it uses ADSL as an example. "In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols." It's in the context of QAM mapper 82 mapping m-tuples groups of bits into QAM symbols, one symbol at a time, tone by tone, inserting overhead channel symbols, which are plural, and phase scrambling is applied to these symbols. ***My interpretation has been applied on a QAM symbol by QAM symbol [i.e., "carrier by carrier"].***

Ex. 2002 at 107:7–108:18 (emphasis added). *See, more generally, id.* at 104:20–109:5.

Thus, Petitioners' expert has interpreted the claim terms "scrambl[e/ing]…a plurality of carrier phases" and "scramble…a plurality of phases" to require adjusting the phases of a plurality of carriers within a single multicarrier symbol. Consequently, the term "scrambl[e/ing]…a plurality of carrier phases"—or the variant "scramble…a plurality of phases"—should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-

randomly varying amounts." *See* Ex. 2003 at ¶ 37.

IV. OVERVIEW OF ASSERTED REFERENCES—SHIVELY AND STOPLER

In every instance, Petitioners allege that the challenged claims are unpatentable at least over Shively in view of Stopler.

A. Shively

Shively discloses a concept intended to increase the useable bandwidth in a multicarrier communications system. Ex. 1011 at 1:5–20. Shively teaches a theoretical way to transmit data over a transmission medium having high signal attenuation at frequencies corresponding to a significant number of carriers. *See* Ex. 2003 at ¶ 43.

To appreciate Shively's teachings, it necessary to understand such impaired transmission mediums. Shively specifically describes "long loop" systems, where the length of cable between transmitting and receiving DSL modems is ***at least*** 18,000 feet (about 3.4 miles):

> Referring to FIGS. 1 and 2, a transmitting modem 31 is connected to a receiving modem 32 by a cable 33 having four twisted pairs of conductors. In long loop systems where cable 3 is of length of the order ***18,000 feet or more***, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed. This characteristic of cable 33 is represented graphically by curve A in FIG. 1.

Ex. 1011 at 9:63–10:2 (emphasis added); *see also, id.,* at 11:11–12 ("Such noisy and/or highly attenuated sub-bands can occur for example in long-run twisted pair

conductors.”). *See* Ex. 2003 at ¶ 44.

FIG. 1 of Shively, which is annotated with color below, is illustrative:

FIG. 1

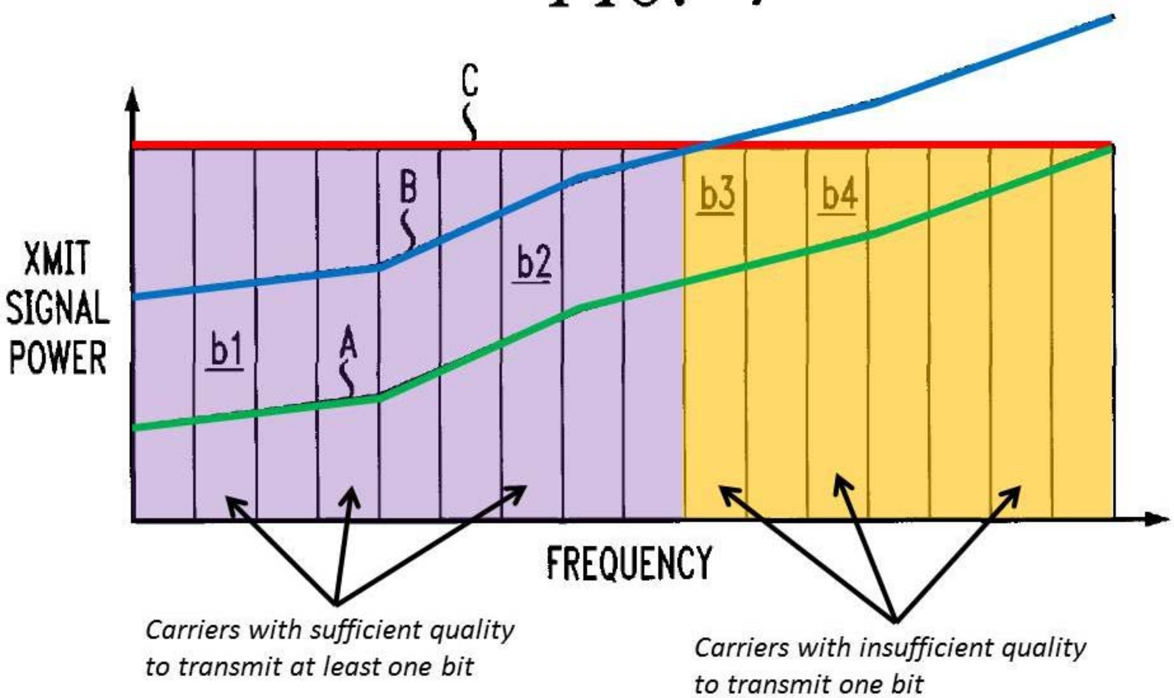


FIG. 1 of Shively shows carriers at increasing frequencies along the x-axis. Each carrier is delineated by vertical lines. Power level is indicated along the y-axis. Green line (A) represents an attenuation/noise floor, which increases as a function of frequency. Ex. 1011 at 2:1–12. Shively explains that attenuation at higher frequencies is a problem across long cables. *Id.* at 9:65–10:2 (“In long loop systems where cable 3 is of length of the order 18,000 feet or more, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed.”). Green line (A) is a characteristic of a communications channel, and it does not

illustrate a transmitted signal. *Id.* at 10:61–11:12. *See* Ex. 2003 at ¶ 45–46.

Blue line (B) is the minimum power margin above the attenuation/noise floor (green line (A)) that is required to transmit a single bit on a given carrier. Ex. 1011 at 2:8–10. Red line (C) illustrates a "spectral density mask," which is a type of power limit imposed by system design. *Id.* at 2:10–12 ("Curve C represents the limits imposed by a power spectral density mask imposed by an external communications standard."). Power transmitted on a given individual carrier cannot exceed red line (C). *See* Ex. 2003 at ¶ 47.

As FIG. 1 illustrates, blue line (B) is below red line (C) for the carriers shaded in purple. In these purple-shaded carriers, there is sufficient headroom to transmit a signal representing at least one bit without exceeding the power limit imposed by the spectral density mask (red line (C)). For the carriers shaded in orange, however, blue line (B) exceeds red line (C). Because the attenuation/noise (green line (A)) for these orange-shaded carriers is too high, a bit cannot be reliably transmitted without exceeding the imposed spectral density mask (red line (C)). In other words, the minimum required power margin (blue line (B)) is greater than the spectral density mask (red line (C)). Ex. 1011 at 10:65–11:3. *See* Ex. 2003 at ¶ 48.

Shively proposes a way to transmit data using some of the impaired (orange-shaded) carriers. Specifically, some of the impaired carriers, although having

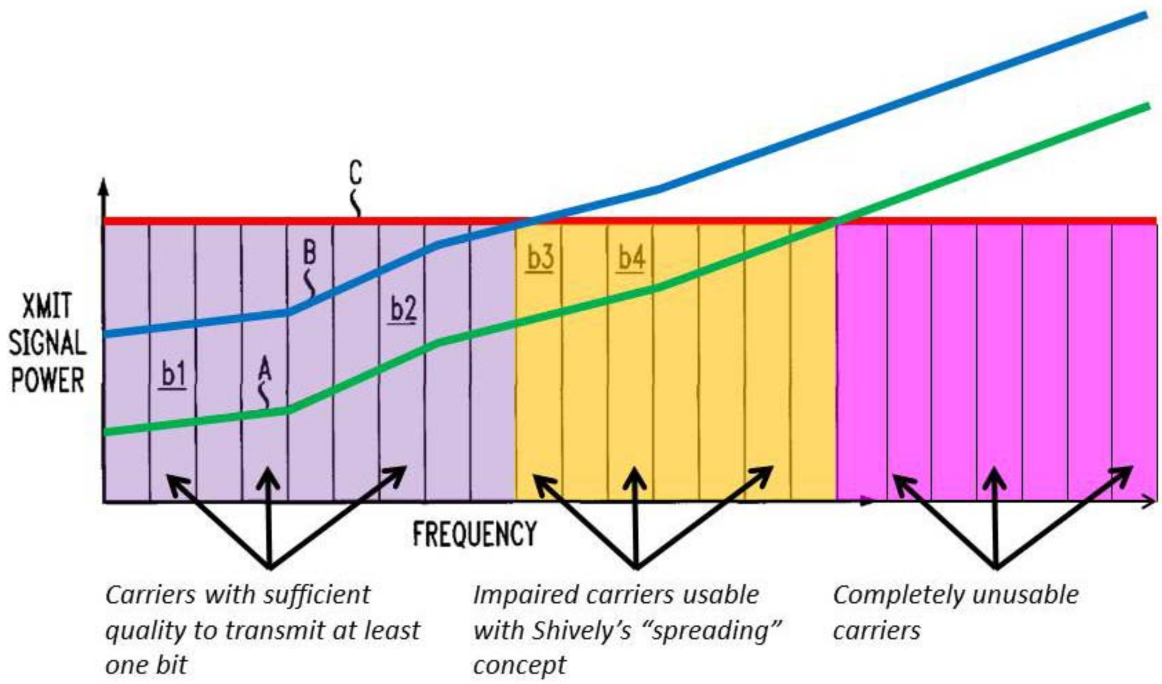
insufficient channel quality to transmit a single bit, have some limited power available between the attenuation/noise floor (green line (A)) and the spectral density mask (red line (C)). Shively makes use of this available power by "spreading" a single bit of data across multiple impaired carriers. *See* Ex. 2003 at ¶ 49.

Shively's receiver combines (adds) the signals that were sent on the impaired carriers to recover the information:

> According to the invention, digital modulator 14 replicates ("spreads") a k-bit symbol over multiple adjacent bands with correspondingly less energy in each band. At the receiving end, detector 49 coherently recombines ("despreads") the redundant symbols in the noisy/attenuated sub-bands. In recombining the symbols, the symbols are simply arithmetically added. Because the noise is incoherent while the signal is coherent, the noise tends to be averaged out while the signal is reinforced by the addition process.

Id. at 11:16–24. *See* Ex. 2003 at ¶ 50.

Although not explicitly depicted in FIG. 1, one having ordinary skill in the art understood that there are carriers in addition to those shaded in purple and orange that are completely unusable under any circumstance—even with Shively's spreading concept. According to this reality, FIG. 1 can be expanded to look like this:



Ex. 2003 at ¶ 51.

The pink-shaded carriers are at frequencies higher than the orange-shaded carriers. The pink-shaded carriers are completely unusable because the attenuation/noise floor (green line (A)) is greater than the imposed spectral density mask power limit (red line (C)). *See* Ex. 2003 at ¶ 52.

Shively discloses two different modes of operation for ADSL-1995: (1) a normal mode; and (2) a "power-boost" mode. The normal mode is referenced by Shively's statement that: "The other limit is on the aggregate power, also defined by an external communication standard, e.g., ANSI Standard T1.413-1995 [(ADSL-1995)] limits the total power for all sub-bands to 100 mWatts." Ex. 1011 at 2:12–15. When referring to the cited ADSL-1995 standard, one having ordinary

skill in the art would have understood that this aggregate power limit corresponds to the normal mode. The standard confirms that the normal mode has an aggregate power limit of 20.4 dBm, which is about 109.6 mW (or approximately 100 mW). Ex. 1017 at p. 65. § 6.13.3 ("The normal aggregate power level shall not exceed…20.4 dBm if all sub-carriers are used[]."). *See* Ex. 2003 at ¶ 53.

The power-boost mode of ADSL-1995 is also described by Shively:

> The power spectral density mask may be dictated by the standard used in a particular country implementing the standard (such as A.N.S.I. standard T1.413-1995 [(ADSL-1995)])…For example, the power limit for frequencies or tones between 0 and 200 kilohertz must be less than -40 dBm/Hz (a power level referenced to one milliwatt over 1 Hz bandwidth). Above 200 kHz (to frequencies in the megahertz of spectrum), the constraint may be -34 dBm/Hz.

Ex. 1011 at 1:51–65. When referring to ADSL-1995, one having ordinary skill in the art would have understood that this spectral density mask scheme—lower power (-40 dBm/Hz) on carriers at frequencies up to 200 kHz and higher power (-34 dBm/Hz) on carriers at frequencies above 200 kHz—describes the ADSL-1995 power-boost mode. *See* Ex. 2003 at ¶ 54.

The power-boost mode is illustrated below in a figure excerpted from the ADSL-1995 standard, Ex. 1017 at p. 66:

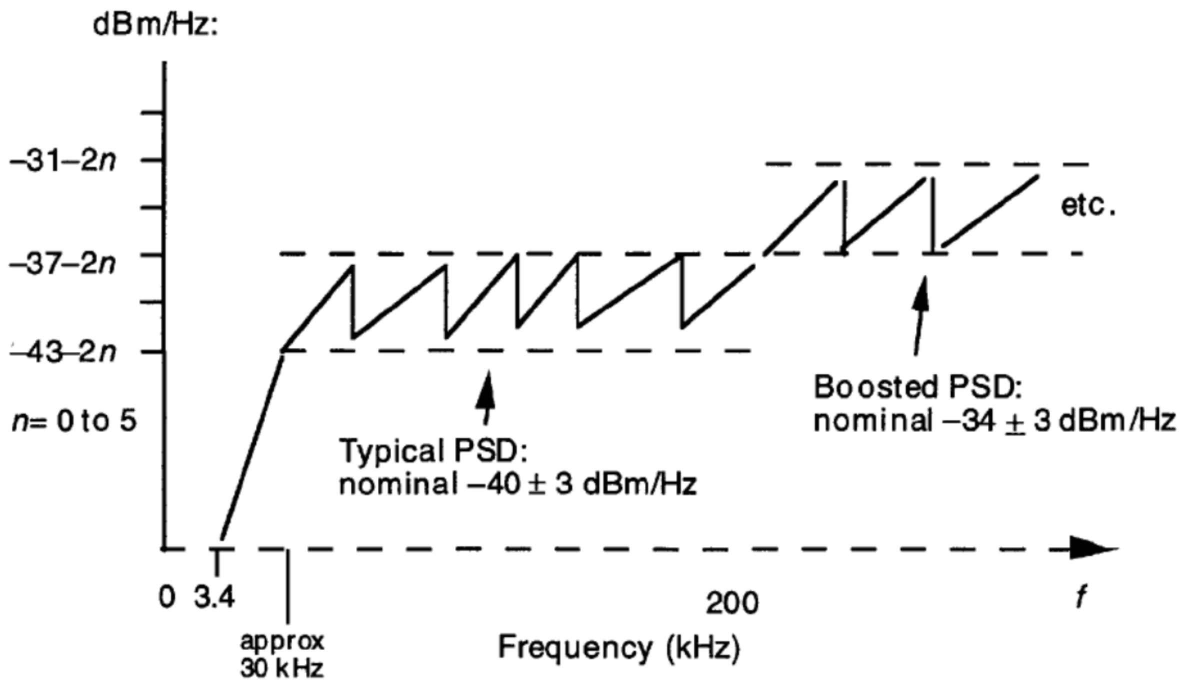


Figure 18 – ATU-C transmitter PSD mask: pass-band detail

Note, in the figure above, "PSD" stands for power spectral density, which corresponds to the spectral density mask power limit. *See id.* at p. 61, § 6.8. *See* Ex. 2003 at ¶ 55.

While the normal mode has an aggregate power limit of approximately 100 mW, the aggregate limit of the power-boost mode is approximately 344 mW. *See* Ex. 1017 at p. 66 ("a power boost…total power = the sum of the powers (-4 + 10log(*ncdown1*)) and (2 + 10log(*ncdown2*)), where *ncdown1* and *ncdown2* are the number of subcarriers used in the sub-bands *i* = 0 to 50, and *i* = 51 to 255, respectively."). Petitioners' expert, however, misunderstood Shively by imagining that a 100 mW aggregate power limit would be used in the power-boost mode. In

particular, during cross-examination regarding the bases for his opinions regarding Shively, he testified that he interpreted Shively as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers in the frequency band up to 200 kHz and -34 dBm/Hz for carriers in the frequency band above 200 kHz and an aggregate power limit of approximately 100 mW. Ex 2002 at 43:7–25; *see, more generally, id*. at 42:10–46:12. But this is clearly wrong because it is wholly inconsistent with the ADSL-1995 standard to which Shively's disclosure is directed. *See* Ex. 2003 at ¶ 56.

Indeed, having such a low aggregate power limit (100 mW, which is less than 1/3 of the actual 344 mW aggregate power limit of power-boost mode in ADSL-1995) would defeat the purpose of having a power-***boost*** mode. Notwithstanding Petitioners' expert's mistaken understanding of Shively—which mixed the aggregate power limit of normal mode with the spectral density mask of power-boost modes—one having ordinary skill in the art would have readily paired the correct aggregate power limit and spectral density mask for a particular mode when consulting the ADSL-1995 standard to which Shively's disclosure is directed.[3] *See* Ex. 2003 at ¶ 57.

[3] To the extent Shively is incorrectly interpreted as disclosing a single mode in which the spectral density mask is -40 dBm/Hz for carriers having frequencies up

In Shively's proposed system using normal mode for ADSL-1995 across 18,000 foot wires, and given the average attenuation/noise characteristics of such a long-loop, about 34% of the carriers would be unimpaired (*i.e.*, would fall into the purple-shaded region of the figure on page 23 *supra*), about 6% of the carriers would be impaired (*i.e.*, would fall into the orange-shaded region of the figure on page 23 *supra*), and about 60% of the carriers would be unusable (*i.e.*, would fall into the pink-shaded region of the figure on page 23 *supra*). Thus, ***more than half of the carriers cannot be used at all***. Consequently, the power of a transmitted signal will be reduced by 60%, thereby resulting in power levels only 40% of maximum. *See* Ex. 2003 at ¶¶ 58–59.

In Shively's proposed system using power-boost mode for ADSL-1995

---

to 200 kHz and -34 dBm/Hz for frequencies above 200 kHz (as is the case for boosted mode of ADSL-1995) and a total power limit of approximately 100 mW (as is the case for the normal mode of ADSL-1995), one of skill in the art would recognize this as an obvious error (Ex. 2003 at ¶ 57). *See In re Yale*, 434 F.2d 666, 668–69 (C.C.P.A. 1970) ("Since it is an obvious error, it cannot be said that one of ordinary skill in the art would do anything more than mentally disregard [the incorrect chemical] as a misprint or mentally substitute [the correct chemical] in its place.").

across 18,000 foot wires, and given the average attenuation/noise characteristics of such a long-loop, about 43% of the carriers would be unimpaired (purple-shaded), about 6% of the carriers would be impaired (orange-shaded), and about 51% of the carriers would be unusable (pink-shaded). Again, more than half of the carriers cannot be used at all. Consequently, the power of a transmitted signal will be reduced by 51%, thereby resulting in power levels only 49% of maximum. *See* Ex. 2003 at ¶ 60–61.

While Shively's "spreading" technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half. Based on worst-case assumptions regarding Shively's spreading technique, the clipping probability for both normal and power-boost modes is virtually zero.[4] *See* Ex. 2003

[4] For the normal mode, the clipping probability is $8.3*10^{-17}$. *See* Ex. 2003 at ¶ 63–67. Assuming a sampling rate of 2.2 MHz for ADSL-1995, this would result in a clipping error ***once every 173.7 years***, on average. *Id.* For the power-boost mode, the clipping probability is $1.4*10^{-15}$. *Id.* Using the same assumption for sampling rate, this would result in a clipping error ***once every 10.3 years***, on average. *Id.* These numbers are many orders of magnitude larger than the error rate of 4.55 seconds discussed above.

at ¶ 63–67.

For cable lengths longer than 18,000 feet, an increasing number of carriers becomes unusable (pink-shaded), resulting in even greater reductions in clipping probabilities. *See* Ex. 2003 at ¶ 68.

Not surprisingly, Shively does not mention anything about clipping or PAR. Petitioners' expert agreed:

> Q. Okay. Can you tell me, does the Shively reference include any discussion of PAR?
>
> A. I don't remember seeing it.
>
> Q. Okay. Does Shively include any explanation it's spreading invention causes an increase in PAR?
>
> A. I don't remember seeing that.
>
> Q. Does Shively explain anywhere that its spreading invention would cause a PAR problem?
>
> A. I don't remember seeing that.
>
> Q. Okay. So the Shively reference itself does not indicate that its invention creates any issue with PAR; right?
>
> A. I didn't see it.

Ex. 2002 at 14:2–15.

B. Stopler

Unlike Shively, Stopler proposes an idea for use with ***both*** multicarrier systems ***and*** "single-carrier" systems. While multicarrier systems transmit a transmission signal that combines multiple carriers each having a phase, a single-

carrier system transmits a signal using only one carrier, which has ***only one phase***. *See* Ex. 2003 at ¶ 69.

Stopler specifically teaches that his concept can be used with single-carrier code-division multiple access ("CDMA") systems. *See, e.g.,* Ex. 1012 at 12:58–63 ("The framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 'Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System.'").[5] *See* Ex. 2003 at ¶ 70.

FIG. 5, which shows Stopler's "framing scheme" (Ex. 1012 at 8:54–55), is illustrative:

[5] As Petitioners' expert explained during cross-examination, some CDMA techniques can be used in a multicarrier system. Ex. 2002 at 110:20–25. However, Stopler only refers to CDMA techniques that are disclosed in two references: (1) TIA/EIA/IS-95; and (2) "Proakis, 'Digital Communications,' Chapter 15." Ex. 1012 at 3:37–47 and 12:58–63. Both TIA/EIA/IS-95 and Proakis are incorporated by reference into Stopler. *Id.* at 3:37–47. Both describe single-carrier CDMA techniques, exclusively. *See* Ex. 2005; Ex. 2006; Ex. 2003 at ¶ 71.

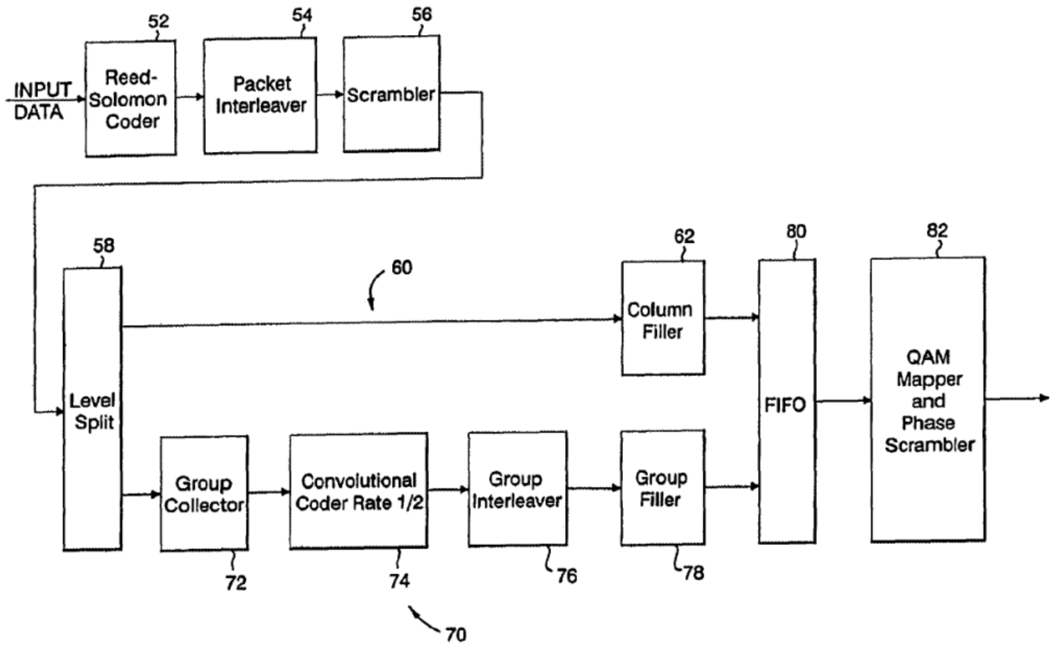


FIG. 5

See Ex. 2003 at ¶ 72.

Significantly, there is a block missing from FIG. 5—namely, a block downstream from the QAM Mapper/Phase Scrambler 82:

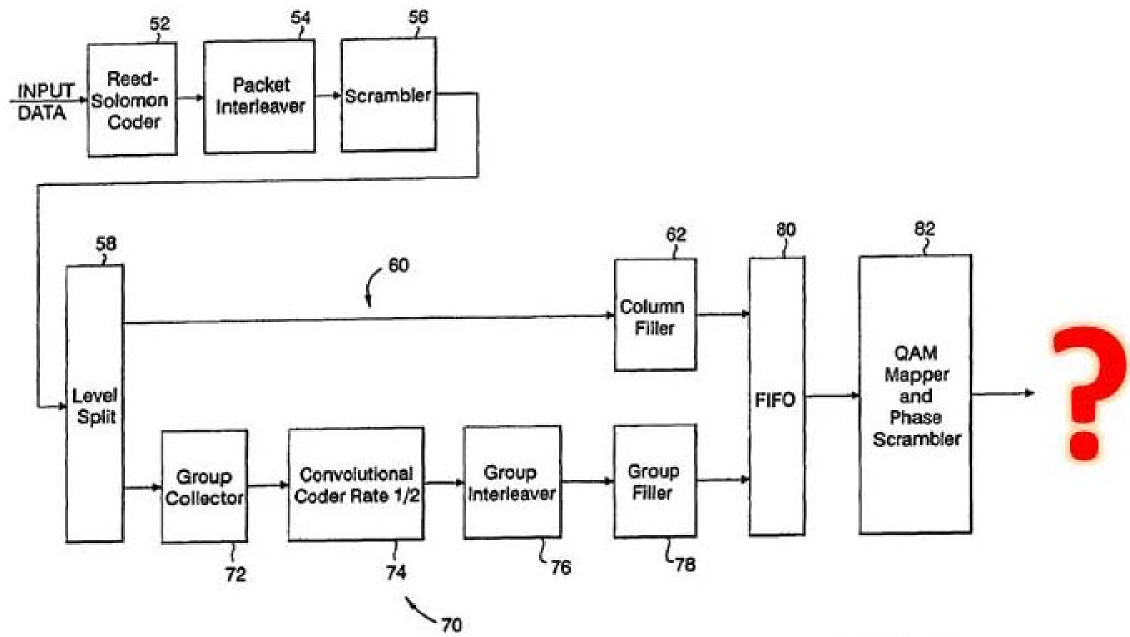
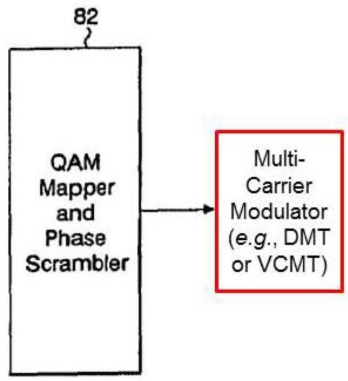


FIG. 5

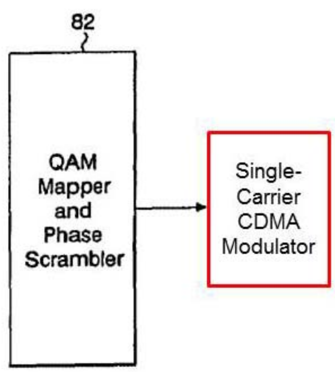
See Ex. 2003 at ¶ 73.

The missing block would specify the type of "modulation" to be used, whether the modulation be single-carrier or multicarrier. *See* Ex. 1012 at 12:55–57 ("The output from the QAM mapper 82 is provided to ***a modulator (not shown)*** which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc.") (emphasis added).[6] *See* Ex. 2003 at ¶ 74. So the missing block downstream from the QAM Mapper/Phase Scrambler 82 could be a multicarrier modulator:

[6] Note, VCMT stands for "variable constellation multitone." *See id.* at 2:9. This is a type of multicarrier technique. Ex. 2003 at ¶ 74.



Or the missing block could be a single-carrier modulator:



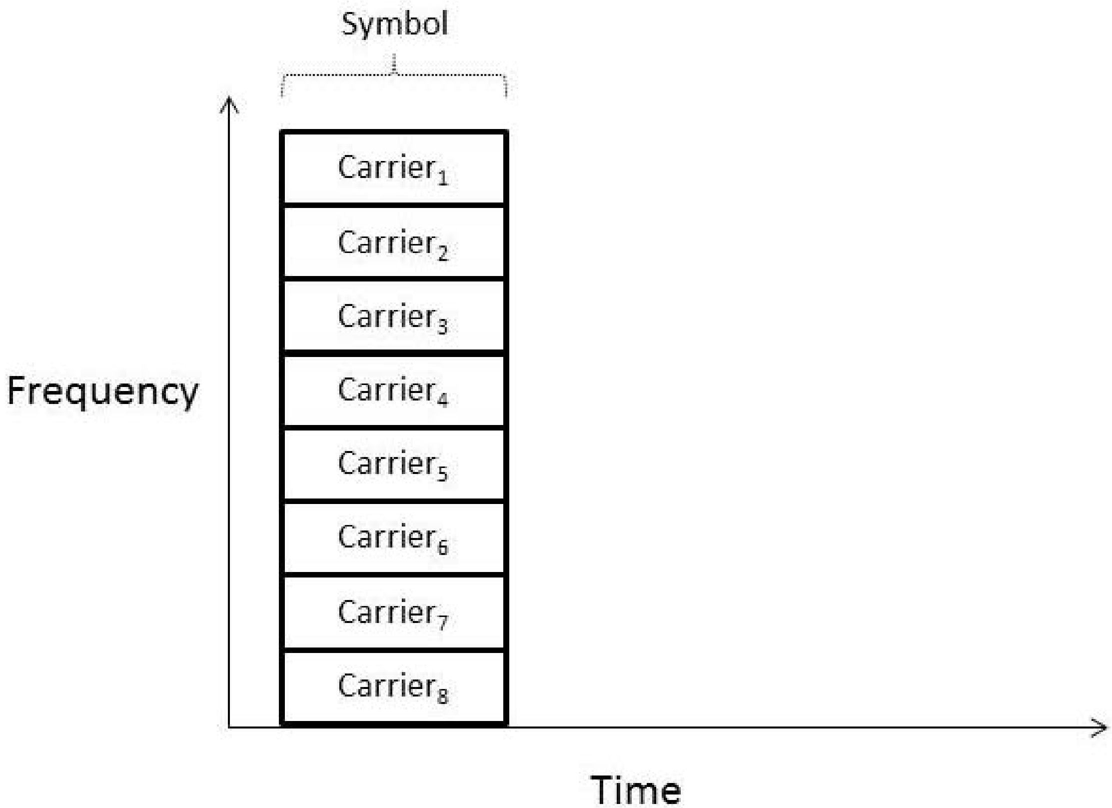
See Ex. 2003 at ¶ 76.

In either case, Stopler's phase scrambling scheme must at least be compatible with single-carrier CDMA. This fact is reflected in Stopler's claims. For example, claim 25 of Stopler recites a "method of arranging and transmitting data in a ***CDMA system***." Ex. 1012 at 16:4–5 (emphasis added). And claim 31, which depends from claim 25, recites "phase scrambling": "31. The method of claim 25, wherein prior to said utilizing step, said method includes the step of ***phase scrambling*** said upper level data and said second encoded data in

accordance with said second encoded data." *Id.* at 16:45–48 (emphasis added). So, plainly, Stopler's phase scrambling idea must be compatible with single-carrier CDMA. *See* Ex. 2003 at ¶ 76.

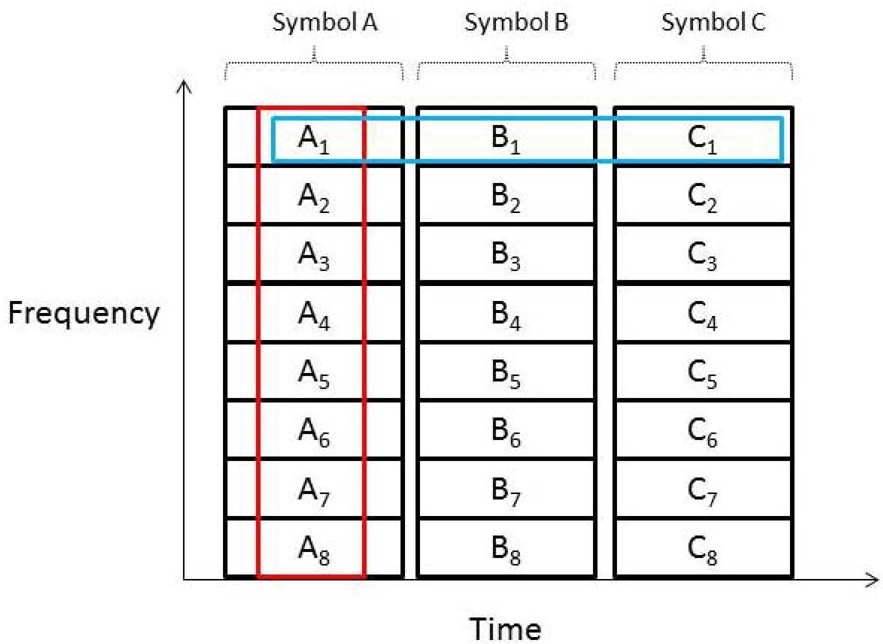
At issue in this IPR is whether Stopler's phase scrambling is performed within a single multicarrier symbol, or whether phase scrambling is performed amongst a plurality of symbols (be they multicarrier or single-carrier), each transmitted at a different time. Because Stopler discloses and claims phase scrambling with a single-carrier CDMA system, one of skill in the art would understand Stopler to disclose the latter—phase scrambling is performed across different symbols in time. Phase scrambling is not performed within a single multicarrier symbol.

Consider the following illustration of a multicarrier symbol:



The symbol includes eight carriers—Carrier_1 to Carrier_8. Each carrier has an associated phase. According to Petitioners' incorrect argument, Stopler discloses scrambling the phases of Carrier_1–Carrier_8. Petition at p. 14 ("Stopler teaches that a phase scrambler can be employed to randomize the phase of the individual [carriers].").

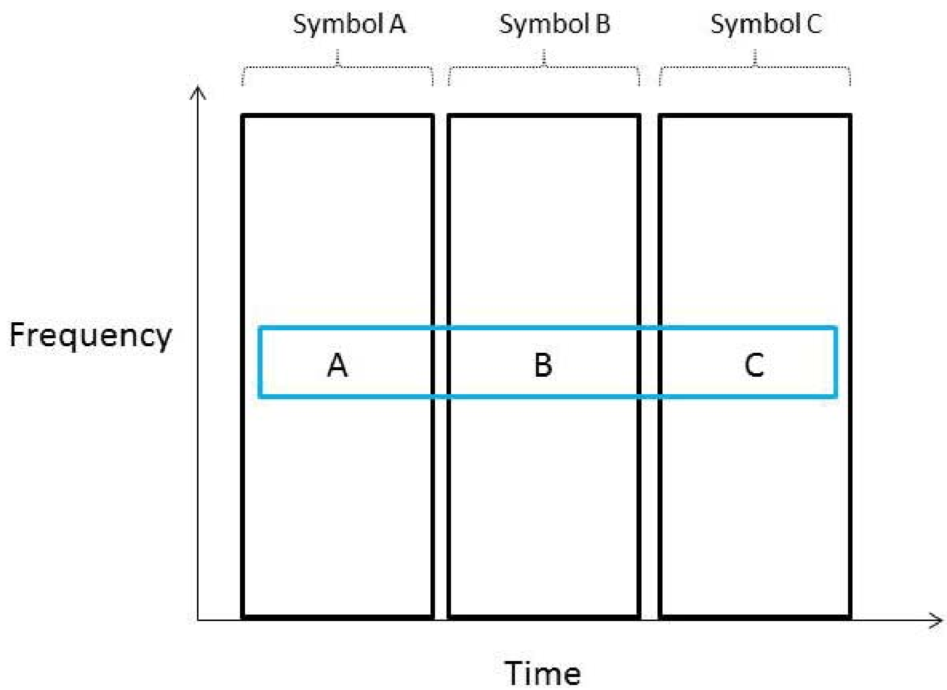
Consider now that three multicarrier symbols are transmitted at different times:



Petitioners argue that Stopler's phase scrambling is performed vertically, within the red box—*i.e.*, within one symbol. Petitioners' expert further asserted (during cross-examination) that Stopler's phase scrambling is not performed horizontally from symbol-to-symbol—*e.g.*, within the blue box. Ex. 2002 at 107:15–18 ("Q. So you're suggesting that each symbol from one symbol to the next would have a different phase rotation? A. No. No. Individual QAM symbols within the same modulation block."); *see, more generally, id.* at 104:20–109:5. This is wrong. *See* Ex. 2003 at ¶ 77.

Petitioners' flawed reasoning is easy to demonstrate, given that single-carrier CDMA must be operable with Stopler's phase scrambling. Single-carrier systems have only one carrier with only one phase. Consider three single-carrier

symbols sent at different times:



It is nonsensical to scramble phases within a symbol because there is only one phase in each symbol. Phase scrambling in a single-carrier system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box. *See* Ex. 2003 at ¶ 78.

There are various reasons that would have been recognizable to one having ordinary skill in the art for performing phase scrambling from symbol-to-symbol. For example, Petitioners' expert suggested that pilot tones could be scrambled over time "not to create a DC bias." Ex. 2002 at 95:7–9; *see, more generally, id.* at 95:3–17. *See* Ex. 2003 at ¶ 79.

Another example for phase scrambling from symbol-to-symbol is detailed in U.S. Pat. No. 6,370,156 ("the '156 patent"), which has a priority date of January 31, 1997 (which is before the November 9, 1999 priority date of the '243 patent). The '156 patent identifies a problem of "narrowbanded" interference in ADSL-1995. Ex. 2004 at 1:55–2:16. This identical problem is also discussed in Stopler, as depicted in FIG. 4:

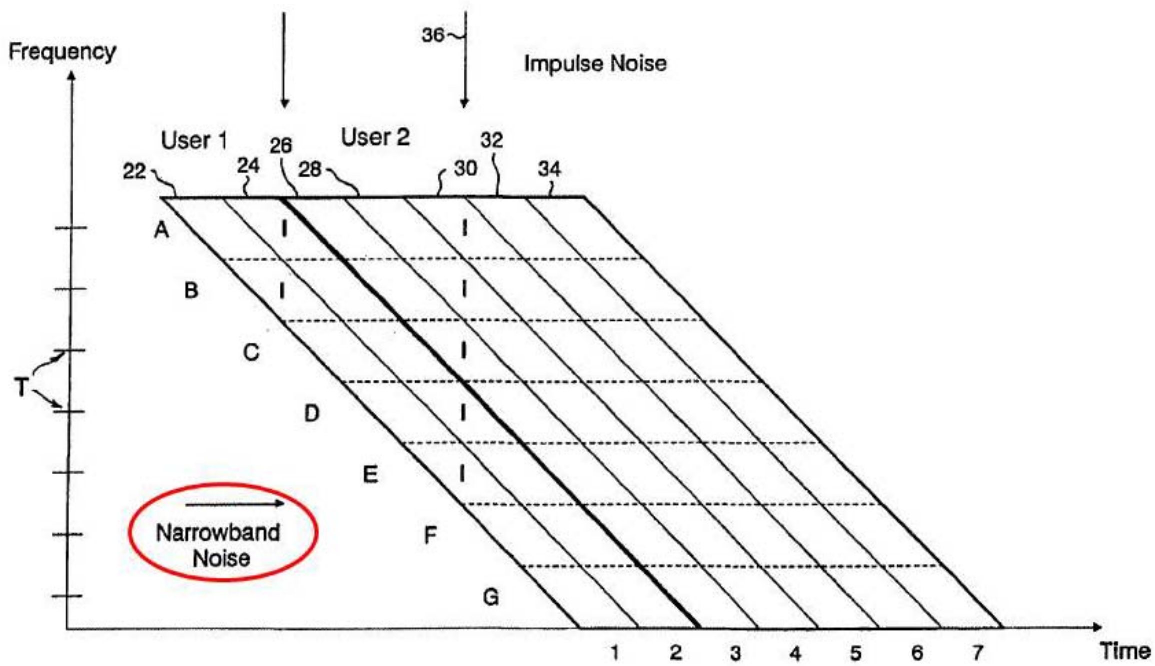


FIG. 4

See Ex. 2003 at ¶ 80.

Stopler further explains: "One type of noise is ingress or narrowband interference which typically occurs at a fixed frequency and lasts for a long time." Ex. 1012 at 1:36–38. Stopler claims that his "invention" "allows efficient

operation in multipoint to point channels which are affected by ingress (narrowband noise) and impulsive (burst) interference." *Id.* at 5:10–14. *See* Ex. 2003 at ¶ 81.

Stopler addresses narrowband noise in two ways. First, as shown in Figure 4 reproduced above, a given carrier (*e.g.*, carrier E) is assigned to a first user (*e.g.*, User 1) at some times and to a different user (*e.g.*, User 2) at other times. If narrowband noise corrupts carrier E, the resulting bit errors have reduced impact on each user compared to a system in which a given carrier is always assigned to a single user. *See* Ex. 2003 at ¶ 82.

This solution works for data, but it will not work for an overhead pilot carrier because such a pilot must be received by all users at all times to allow the receiver of each user to remain synchronized with the transmitter. Thus, narrowband noise at the frequency of pilot tones must be addressed differently. *See* Ex. 2003 at ¶ 82.

According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82.

The teachings of the '156 patent reveal how Stopler's inter-symbol phase scrambling concept reduces the problem of narrowband noise that interferes with a

pilot carrier. The '156 patent explains that ADSL-1995 has ***one*** carrier that is assigned to be a pilot. Ex. 2004 at 1:61–63 ("As is indicated in [the ADSL-1995 standard], one of the carriers is reserved as a pilot carrier."). Then, the technique of phase scrambling the pilot carrier from symbol-to-symbol is explained:

> In a particular implementation of the present invention, the pilot carrier is modulated as a random or pseudo-random signal. In this way, by modulating a randomised signal on the pilot carrier, the state of the pilot carrier in the constellation scheme ***will change randomly*** so that the demodulation will have a good averaging effect resulting in an ***increase of the interference immunity***.

Id. at 4:39–47 (emphasis added).

> It is to be remarked that, to have significant immunity against interferers, the data elements which are modulated on the pilot carrier, [have] to be sufficiently ***random*** so that the pilot carrier reaches all states in the constellation scheme and a good averaging of the interference is obtained by demodulation. This can be obtained by ***scrambling***.

Id. at 5:11–17 (emphasis added). *See* Ex. 2003 at ¶ 83.

Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones. Yet the Petition and accompanying declaration do not discuss or allude to even one system or standard that uses multiple pilot tones in a single symbol. Instead, Petitioners and their expert identify only ADSL (Petition at p. 12; Ex. 1009 at ¶ 58). But, as explained in Petitioners' own exhibit (Ex. 1017), ADSL has exactly ***one*** pilot tone in a symbol, not multiple pilot tones. Ex. 1017 at p. 62, § 6.9.1.2. *See* Ex. 2003 at ¶ 84.

Petitioners and their expert highlight the ADSL standard and admit that it is implemented in Stopler. Petition at p. 12 ("Stopler also explains that its signal transmission scheme may implement techniques of DSL standards such as 'ADSL (Asymmetric Digital Subscriber Line).'"); Ex. 1009 at ¶ 58. Starting with the next sentence, Petitioners and their expert state:

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60–62 & 12:51–54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24–26. A POSITA would have understood that the values transmitted in an overhead channel may not be random, and in fact, ***may be highly structured***. Ex. 1009, p. 24. Without the phase scrambler, the ***structured*** nature of the overhead channel could contribute to an increase in the peak-to-average power ratio of the transmitter. Ex. 1009, pp. 24–25.

Petition at pp. 12–13 (emphasis added); *see also* Ex. 1009 at ¶ 59. *See* Ex. 2003 at ¶ 85.

Petitioners' expert, upon cross-examination, clarified that what he meant by "highly structured" is that multiple pilot tones are present in a single symbol. Ex. 2002 at 105:11–20 ("Q. …What do you mean by 'highly structured'? A. For example, if the pilot tone is the same value in all overhead channels, that's an example of structured; repeating the same value multiple times."); and 109:1–5 ("A.…[Stopler] specifically says 'overhead symbols,' which could be interpreted to having two or more overhead symbols in one block. And that was my interpretation. It still is my interpretation."); *see, more generally, id.* at 104:20–

109:5. *See* Ex. 2003 at ¶ 85

But Petitioners' expert ***did not even realize that ADSL has only <u>one</u> pilot tone***. Ex. 2002 at 90:11–14 ("Q. Okay. So in an ADSL system, according to the T1.413 standard, for example, there's a single pilot tone; correct? A. I don't know that."); *see, more generally, id.* at 90:4–91:16. At best, Petitioners' expert's declaration is based on incomplete information about ADSL. *See* Ex. 2003 at ¶ 85.

Instead of understanding that ADSL has only one pilot tone, Petitioners' expert based his opinion on the fact that Stopler refers to "overhead carriers" and that these multiple symbols must be in one symbol. Ex. 2002 at 109:1–5.[7] But the correct interpretation of Stopler's reference to plural "overhead carriers" is that (a) there is one overhead pilot carrier per symbol and (b) there are multiple symbols. *Ergo*, Stopler refers to multiple overhead carriers. *See* Ex. 2003 at ¶ 86.

As demonstrated by the '156 patent, it was known by those with skill in the

[7] Petitioners' expert specifically testified: "[Stopler] specifically says 'overhead symbols,' which could be interpreted to having two or more overhead symbols in one block. And that was my interpretation. It still is my interpretation." Ex. 2002 at 109:1–5. To clarify a matter of terminology, (1) "overhead symbols" correspond to "carriers," and (2) "block" corresponds to "symbol" as used in this Patent Owner Response. *See* Ex. 2003 at ¶ 86.

art to scramble the phases on a pilot carrier from one single-carrier symbol to the next in order to reduce the problem of narrowband noise, a problem recognized by Stopler. Petitioners' expert's uninformed view, by contrast, is that Stopler's phase scrambling would be performed within one multicarrier symbol to reduce PAR. Ex. 1009 at ¶ 60. Stopler, however, is silent on issues related to PAR, and, in fact, does not mention the word "power" or PAR, or teach that its disclosure could be used to resolve PAR problems, as confirmed by Petitioners' expert:

> Q. Okay. And Stopler does not mention peak-to-average power ratio, does it?
>
> A. I did not see it.
>
> Q. Okay. And it doesn't state anywhere that it's addressing a PAR issue; correct?
>
> A. I didn't see that.
>
> Q. And it doesn't say anywhere that its teachings could potentially reduce PAR; correct?
>
> A. I didn't see it.
>
> Q. Okay. Would you be surprised if I told you that the Stopler reference doesn't even mention the word "power"?
>
> A. I didn't see it. I'm not surprised.

Ex. 2002 at 97:6–18. *See* Ex. 2003 at ¶ 87.

Indeed, there is no reason that Stopler would discuss PAR because there is no basis for concluding that Stopler has a PAR problem, and Stopler's technique of scrambling phases from one symbol to the next does not reduce PAR. *See* Ex. 2003 at ¶ 88.

Instead of Petitioners' theory about reducing PAR, Stopler sheds some light as to why he suggests performing "phase scrambling." Stopler's only stated reason for scrambling phases is "to randomize the overhead channel <u>symbols</u>" plural. Ex. 1012 at 12:24–26. Because Stopler must be compatible with single-carrier CDMA as discussed above, the only reasonable conclusion is that Stopler's reference to "overhead channel symbols" plural refers to scrambling phases from symbol-to-symbol. *See* Ex. 2003 at ¶ 89.

Furthermore, Stopler states that the phase scrambler is "applied to all symbols, not just the overhead symbols" in order "to simplify implementation." But performing phase scrambling according to Petitioners' interpretation—*i.e.*, every carrier is scrambled within a symbol such that the signals on each of the carriers within a symbol have a random distribution of phase adjustments—would ***add complexity*** to Stopler's system. Instead, the only simplifying way to execute Stopler's directive is to adjust the phases of all carriers within a single symbol by the same amount. *See* Ex. 2003 at ¶ 90.

V. PETITIONERS HAVE NOT PROVEN UNPATENTABILITY FOR THE CLAIMS OF THE '243 PATENT

The Petition fails to prove, by a preponderance of the evidence, that any claim of the '243 patent is unpatentable because (1) there is no credible or accurate evidence demonstrating why one having ordinary skill in the art would have combined Shively and Stopler, and (2) Stopler does not disclose phase scrambling

as recited in the claims. Instead, Petitioners misunderstand the teachings of these references, make unsupported assumptions having no basis in fact, and, ultimately rely on only hindsight bias to cobble together the references.

A. Petitioners' Argued Reasons To Combine Shively And Stopler Are Without A Rational Basis, Based On Factual Errors, And Suffer From Hindsight Bias

Every assertion of invalidity is based on a combination of Shively and Stopler. But virtually all of Petitioners' (and Petitioners' expert's) assumptions regarding reasons to combine Shively and Stopler are without a rational basis, factually wrong, and suffer from hindsight bias.

1. Petitioners Provide No Explanation For The "Use Of A Known Technique To Improve A Similar Device" Rationale To Combine Shively And Stopler

Petitioners argue that the combination of Shively and Stopler "is merely a use of a known technique to improve a similar device, method, or product in the same way." Petition at p. 13. Petitioners, however, fail to apply this boilerplate rationale to Shively and Stopler, leaving the following questions unanswered. What is the "known technique"? What device/method/product is "similar"? How is the alleged "known technique" used for improvement in the "same way"?

When relying on this rationale, the USPTO requires much more in the way of explanation:

> C. Use of Known Technique To Improve Similar Devices (Methods, or Products) in the Same Way

> To reject a claim based on this rationale, Office personnel must resolve the Graham factual inquiries. Office personnel must then articulate the following:
>
> (1) a finding that the prior art contained a "base" device (method, or product) upon which the claimed invention can be seen as an "improvement;"
>
> (2) a finding that the prior art contained a "comparable" device (method, or product that is not the same as the base device) that was improved in the same way as the claimed invention;
>
> (3) a finding that one of ordinary skill in the art could have applied the known "improvement" technique in the same way to the "base" device (method, or product) and the results would have been predictable to one of ordinary skill in the art; and
>
> (4) whatever additional findings based on the Graham factual inquiries may be necessary, in view of the facts of the case under consideration, to explain a conclusion of obviousness.

Examination Guidelines for Determining Obviousness Under 35 U.S.C. 103 in View of the Supreme Court Decision in *KSR International Co. v. Teleflex Inc.*, 72 Fed. Reg. 57,530 (October 10, 2007). As the Board explained:

> Patent Owner argues that "(1) Petitioner NEVER explains what is allegedly lacking in the base reference, (2) Petitioner NEVER points out the differences between the claimed invention and the base reference or cited art, (3) Petitioner NEVER explains how the base reference should be allegedly modified, (4) Petitioner NEVER explains what modification would have been obvious, and (5) Petitioner NEVER explains what modifications to each base reference would have allegedly been made." Prelim. Resp. 47-48.
>
> We agree.

Naughty Dog, Inc. v. McRo, Inc., IPR2014-00198, Paper no. 9 at p. 21 (P.T.A.B. May 18, 2014).

In the present case, Petitioners' alleged reason to combine Shively and Stopler does not provide even basic answers to these questions.

2. Petitioners Wrongly Claim That Shively's Transmitter Suffers From An Increased PAR

Petitioners contend: "A POSITA would have recognized that by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio [(PAR)]." *Id.* As discussed above in § IV.A, however, this assertion is wrong. Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather, Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic).

Petitioners have it backwards. To the extent one having skill in the art would have even considered the issue of PAR in view of Shively's disclosure (which does not itself discuss PAR), they would have concluded that Shively's transmitter, in fact, does ***not*** suffer from increased PAR. Instead, there would have been recognition that the transmission signal strength is low due to unusable carriers, and therefore the clipping probability would be virtually zero. *See* § IV.A above.

Furthermore, Petitioners' expert's declaration states only in relative terms that there is an "increase" in PAR. An "increase" of how much? An increase with respect to what? Petitioners' expert's declaration lacks any factual basis for

the claim of "increased" PAR. Petitioners' expert provides no calculations or data that illustrate to what degree there is an "increase" in PAR with Shively's transmitter. Ex. 1009 at ¶¶ 63–64. *See* 37 C.F.R. § 42.65(a) ("Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight."); *In re Am. Acad. of Sci. Tech Ctr.*, 367 F.3d 1359, 1368 (Fed. Cir. 2004) (explaining that "the Board has broad discretion" to weigh declarations and "conclude that the lack of factual corroboration warrants discounting the opinions expressed"); *Rohm & Haas Co. v. Brotech Corp.*, 127 F.3d 1089, 1092 (Fed. Cir. 1997) ("Nothing in the [federal] rules [of evidence] or in our jurisprudence requires the fact finder to credit the unsupported assertions of an expert witness."); *Ashland Oil, Inc. v. Delta Resins & Refractories, Inc.*, 776 F.2d 281, 294 (Fed. Cir. 1985) ("Lack of factual support for expert opinion going to factual determinations…may render the testimony of little probative value….").

By contrast, Dr. Short's declaration in support of this Patent Owner Response explains in detail why any arguable "increase" in PAR due to Shively's "spreading" scheme is trivial in view of Shively's drastic reduction in transmission signal power (which virtually eliminates clipping). *See* Ex. 2003 at ¶¶ 61–67.

Without any supporting calculations or data, and without even a qualitative discussion of what would constitute a problematic PAR, Petitioners' expert's

declaration should not be given any weight. *See* 37 C.F.R. § 42.65(a).

3. Petitioners' Justification For Combining Shively And Stopler Uses The '243 Patent As A Roadmap And Suffers From Hindsight Bias

Petitioners allege that "[h]aving phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time." Petition at p. 14. Yet, as admitted by Petitioners' expert, this is not mentioned or even alluded to in Shively or Stopler. Ex. 2002 at 14:2–15 and 97:6–18. Actually, out of all the evidence in this *inter partes* review, only the inventor of the '243 patent recognized the problem of high PAR due to phase-aligned carriers.

Besides the say-so of Petitioners' expert, the ***only cited evidence***—that high PAR results from transmitting the same data on multiple carriers—***is from the '243 patent***. Petition at p. 14; Ex. 1009 at ¶ 64. Here, Petitioners quite literally use the '243 patent as a roadmap for arriving at their theory of obviousness. This is a textbook case of impermissible hindsight bias. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 421 (2007) ("A factfinder should be aware, of course, of the distortion caused by hindsight bias and must be cautious of arguments reliant upon *ex post* reasoning."); *Insite Vision Inc. v. Sandoz, Inc.*, 783 F.3d 853, 859 (Fed. Cir. 2015) ("Defining the problem in terms of its solution reveals improper hindsight in the selection of the prior art relevant to

obviousness.”) (quoting *Monarch Knitting Mach. Corp. v. Sulzer Morat GmbH*, 139 F.3d 877, 881 (Fed. Cir. 1998)); *Texas Instruments Inc. v. Vantage Point Tech., Inc.*, IPR2014-01105, Paper No. 8 at p. 17 (P.T.A.B. January 5, 2015) (“This is an impermissible use of the ’750 patent’s description of the invention as a roadmap to piece together the prior art.”) (citing *InTouch Technologies, Inc. v. VGO Commc’ns, Inc.*, 751 F.3d 1327, 1351 (Fed. Cir. 2014)).

4. There Is No Need To Solve Shively’s Non-Existent PAR Problem

Petitioners state: “Since a high PAR brings numerous disadvantages, a POSITA would have sought out an approach to reduce the PAR of Shively’s Transmitter.” Petition at p. 14. As discussed in § IV.A, however, Shively does not present a problem with PAR. Because Shively does not disclose a system with a PAR problem, one having ordinary skill in the art would have had no reason to look for a solution. *See Runway Safe LLC v. Engineered Arresting Systems*, IPR2015-01921, Paper No. 9 at p. 11 (P.T.A.B. February 29, 2016) (“[W]e are not persuaded that a non-uniformity problem exists with Angley ’025’s cellular concrete system, and Petitioner has not provided adequate proof on that issue. Therefore, we are not persuaded by Petitioner’s rationale for why a person of ordinary skill in the art would have replaced Angley ’025’s cellular concrete blocks with ceramic foam.”).

5. Stopler Does Not Reduce PAR In A Multicarrier Transmitter

Petitioners incorrectly argue that "Stopler provides a solution for reducing the PAR of a multicarrier transmitter." Petition at p. 14. As discussed in § IV.B, Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-carrier.

6. Stopler And Shively Could Not Be Combined

Without any supporting explanation, Petitioners baselessly claim that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." Petition at p. 15. This is wrong. Quite the opposite; Shively and Stopler are incompatible.

It would not be possible to incorporate Shively's bit-spreading concept into Stopler. While Shively shows a point-to-point system (one transmitter and one receiver), Stopler teaches a point-to-multipoint system (one transmitter and multiple receivers). Figure 4 of Stopler is illustrative:

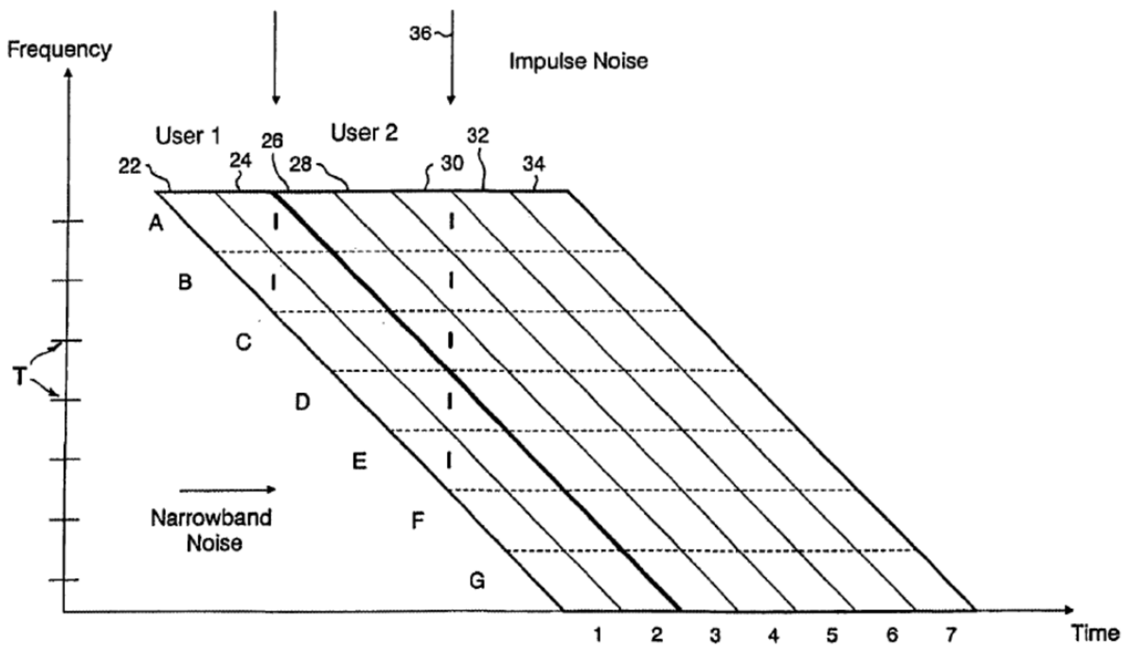
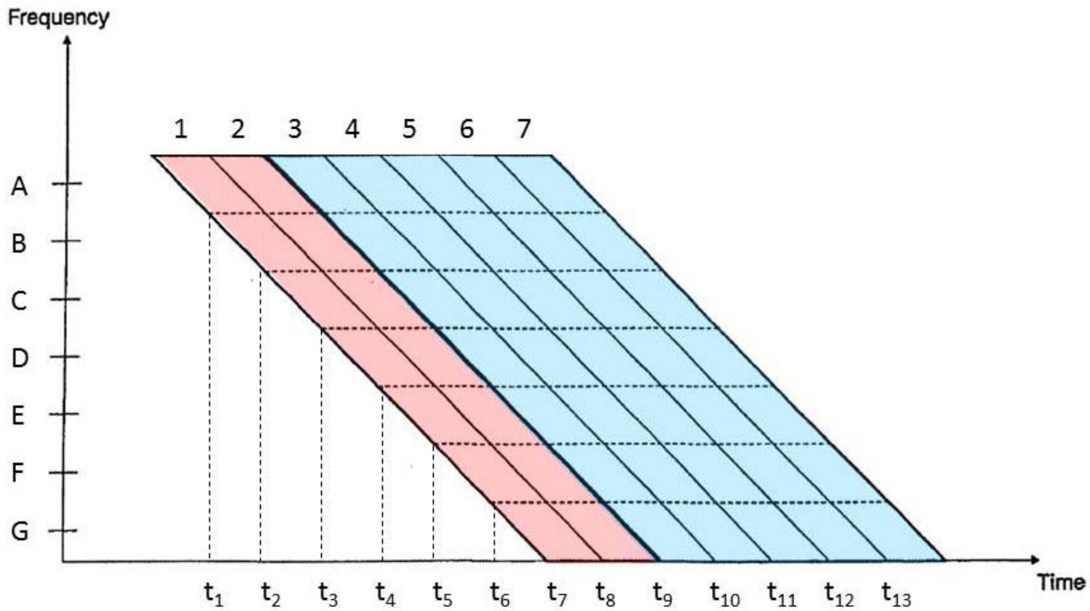


FIG. 4

See Ex. 2003 at ¶ 91.

In Stopler's point-to-multipoint example, User 1 receives data in diagonals 1 and 2, while User 2 receives data in diagonals 3–7. Ex. 1012 at 8:36–39 ("In the illustrated example, the data packet for User 1 consists of two diagonals 22, 24, while the data packet for User 2 consists of five diagonals, 26, 28, 30, 32 and 34."). This is depicted in a modified version of Figure 4 below where User 1's data is shown in red and User 2's data is shown in blue:

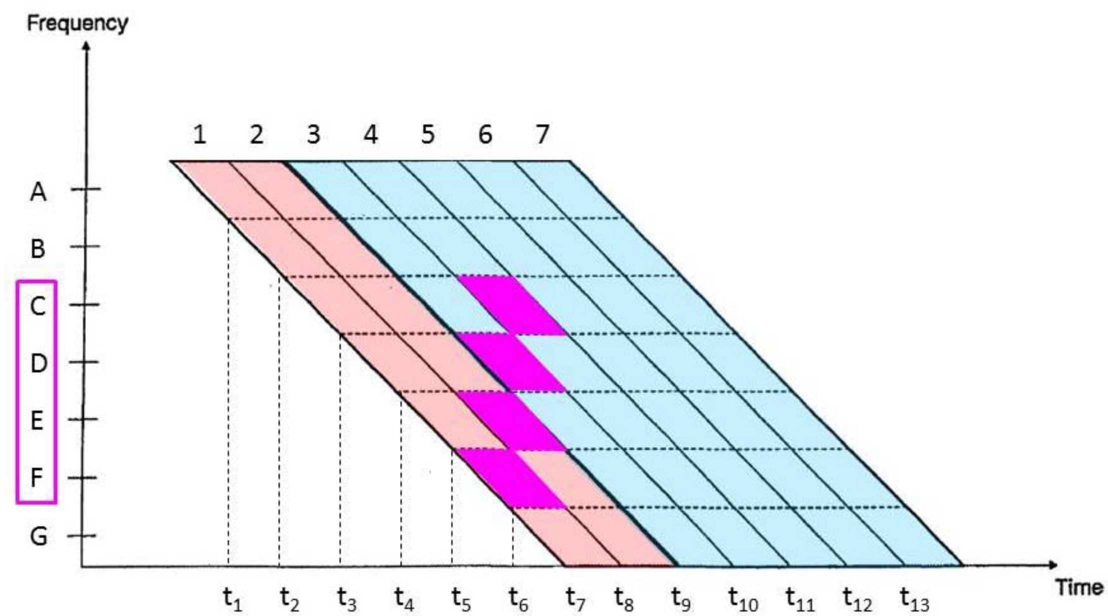


See Ex. 2003 at ¶ 92.

Also depicted in the illustration above along the horizontal time axis are times (t_1–t_{13}) at which successive multicarrier symbols are transmitted. Each symbol includes carriers A–G as illustrated along the vertical frequency axis, however, unlike a point-to-point multicarrier system, at t_1, only carrier A is intended for User 1; at t_2, only carriers A and B are intended for User 1; at t_3, only carriers B and C are intended for User 1 while carrier A is now intended for User 2, and so on. Stopler refers to this technique as "diagonalization." Ex. 1012 at 6:20–22 ("FIG. 4 is an illustration of diagonalization in accordance with the present invention for multitone data transmission as a function of time."). *See* Ex. 2003 at ¶ 93.

If one were to attempt to combine Stopler with Shively's bit-spreading,

multiple carriers must be used. Using Shively's example of four carriers, assume carriers C, D, E, and F, are used for bit-spreading. These carriers are highlighted in the pink rectangle:



See Ex. 2003 at ¶ 94.

Taking the example of a multicarrier symbol transmitted at time t_6, a spread bit over four carriers C–F (pink rhombuses), the spread bit would cross over from User 1 data to User 2 data. So part of the spread bit would be received by User 1 and not User 2, and conversely, the remaining part of the spread bit would be received by User 2 and not User 1. Because all of the bit-spreading carriers are not received by the same user, it would be impossible for User 1's or User 2's receiver to reconstruct the bit. *See* Ex. 2003 at ¶ 95.

Additionally complicating the combination of Shively and Stopler is that

the data intended for User 1 is different than the data intended for User 2. And further, the attenuation/noise characteristics for the communication channel to User 1 may be different from that of User 2. Thus, it would be unduly complex, if not impossible to keep track of what carriers to use for Shively's spreading. In other words, Shively's technique will not work with Stopler. Even Petitioners' expert, under cross-examination, admitted that Shively and Stopler are incompatible. Ex. 2002 at p. 144:22–145:1 ("Somebody learning the teachings of Shively working in the DSL space would not attempt to marry Shively with a system that each QAM signal goes into a different DMT symbol and has huge latency."); *see, more generally, id.* at 138:24–145:1. *See* Ex. 2003 at ¶ 96.

7. There Were No "Market Forces" In Effect To Prompt The Combination Of Shively's And Stopler's Techniques

Again without support or explanation, Petitioners rely on the following vague and conclusory justification for combining Shively and Stopler: "***Market forces*** would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Petition at p. 15 (emphasis added). Petitioners and their expert, however, do not identify or explain such "market forces." The Petition and the supporting declaration do not identify a single product or standard that employs any of the ideas disclosed in Shively or

Stopler.

Nor was Petitioners' expert, upon questioning, aware of any product or standard that uses Shively's spreading concept:

> Q. Okay. But let's focus on the Shively spreading technique that you referenced in your declaration which is taking a single bit and spreading it across multiple carriers.
>
> A. So in the context of repeating 1 bit, 1 or more bits little m or more times, do I know of any product that uses that concept?
>
> Q. Correct.
>
> A. I can't recall.
>
> Q. Okay. And can you think of any standard that uses that technique?
>
> A. No. The DSL standards will be useful. It will be a useful application for DSL type loops but I don't know if any of them actually uses Shively's ideas.
>
> Q. But of all those DSL standards, you're not aware of any of them using Shively's spreading technique?
>
> A. I don't know of any of them.
>
> Q. So the answer is no?
>
> A. No.

Ex. 2002 at 135:11–136:11; *see, more generally, id.* at 134:24–137:16.

Without any evidence that Shively's transmitter ever existed, Petitioners' argument regarding "market forces" makes no sense. Petitioners allege that it would have been obvious to modify Shively's transmitter (*i.e.*, the base product) by adding Stopler's phase scrambler. Petition at p. 15; Ex. 1009 at ¶ 68. But how

would "market forces" apply when there is no evidence that Shively's transmitter—the base product—existed? Surely, there must be a "market" in order for "market forces" to apply.

When asked about his testimony regarding Shively and "market forces," Petitioners' expert acknowledged that his opinion was speculative:

> Q. What's your basis for suggesting that Shively's technique would be motivated by market forces, then?
>
> * * *
>
> A. I ***believe*** it's good technology. It's a good idea. I would ***believe*** some people ***would have*** tried it or used it. It's a good technology for subchannels that don't have enough signal to get a bit across. It repeats across multiple subchannels, make sure you scramble afterwards.

Ex. 2002 at 137:24–138:9 (emphasis added).

Without any evidence that there was a market for Shively's concept before the invention of the '243 patent (or ever), the notion that market forces would have prompted the modification of Shively's transmitter is meaningless. Petitioners' expert's declaration, therefore, is baseless, and the Petition is fact-free. *See* 37 C.F.R. § 42.65(a) ("Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.").

B. Stopler Does Not Disclose Phase Scrambling

All of the independent claims recite phase scrambling, with slightly different

variants:

- Claim 1—"*scrambling, using the phase scrambler, a plurality of carrier phases*";
- Claim 7—"*a phase scrambler operable to scramble a plurality of carrier phases*";
- Claim 13—"*the phase scrambler is operable to scramble a plurality of phases*"; and
- Claim 20—"*the phase scrambler scrambles a plurality of phases*."

As discussed above in § III.C, these terms should be construed to require a phase scrambler that operates by "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts."

Petitioners incorrectly allege that Stopler discloses this type of phase scrambling: "A POSITA would have recognized that modulating phase scrambled symbols onto ***multiple carriers***, as taught by Stopler, results in the 'scrambling' of 'a plurality of carrier phases.'" Petition at p. 22 (emphasis added). *See also* Ex. 1009 at p. 41 ("Accordingly, a POSITA would have understood that Stopler's phase scrambling of the symbols results in phase rotating ***the carrier phases*** when the symbols are modulated onto the carriers.") (emphasis added).

As discussed above in § IV.B, however, Stopler only discloses scrambling phases from one symbol to the next symbol in time, and not with respect to

multiple carriers in a single multicarrier symbol. Because Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol.

Because Stopler does not disclose phase scrambling as claimed in the ’243 patent, Petitioners have not demonstrated by a preponderance of evidence that any of the independent claims (1, 7, 13, and 20) are unpatentable. And accordingly, Petitioners’ assertion of unpatentability for the dependent claims (2–6, 8–12, 14–19, and 21–25) also falls short.

VI. CONCLUSION

For at least the foregoing reasons, TQ Delta respectfully requests that the Board find that Petitioners have not established that any challenged claim is unpatentable.

Dated: February 24, 2017

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CUSTOMER NUMBER: 23446

CERTIFICATE OF WORD COUNT

I hereby certify that this Preliminary Patent Owner Response complies with the word count limit of 37 CFR §42.42. The word count, including footnotes, is approximately 11,000 words as measured by Microsoft Word.

CERTIFICATE OF SERVICE

I hereby certify that the Patent Owner Preliminary Response to Petition for *Inter Partes* Review Pursuant to 35 U.S.C. §§ 42.107 in connection with *Inter Partes* Review Case IPR2016-01020 was served on this 24th day of February, 2017 by electronic mail to the following:

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Paper 12
Entered: February 27, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DISH NETWORK, LLC,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2017-00254
Patent 9,014,243 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

DESHPANDE, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

Petitioner's Motion for Joinder
37 C.F.R. § 42.122(b)

I. INTRODUCTION

DISH Network, L.L.C. ("Petitioner" or "Dish") filed a Petition for *inter partes* review of claims 1–25 of U.S. Patent No. 9,014,243 B2 (Ex. 1001, "the '243 patent"). Paper 3 ("Pet."). Concurrently with its Petition, Dish filed a Motion for Joinder with *Cisco Systems, Inc. v. TQ Delta, LLC,* Case IPR2016-01020 ("the Cisco IPR"). Paper 2 ("Mot."). Dish represents that the petitioner in the Cisco IPR—Cisco Systems, Inc.—does not oppose the Motion for Joinder. Mot. 2. TQ Delta, LLC ("Patent Owner") submits that it does not oppose joinder. *See* Paper 7. Patent Owner also elected to waive its Preliminary Response. *Id*.

For the reasons explained below, we institute an *inter partes* review of claims 1–25 of the '243 patent and grant Dish's Motion for Joinder.

II. RELATED PROCEEDINGS

Petitioner and Patent Owner identify several pending judicial matters as relating to the '243 patent. Pet. 1–2; Mot. 2–3; Paper 5, 2–3.

In the Cisco IPR, we instituted an *inter partes* review of claims 1–25 of the ’243 patent on the following grounds:

References	**Basis**	**Challenged Claims**
Shively[1] and Stopler[2]	§ 103(a)	1–3, 7–9, 13–16, and 20–22
Shively, Stopler, and Gerszberg[3]	§ 103(a)	4–6, 10–12, 17–19, and 23–25

Cisco Systems, Inc. v. TQ Delta, LLC, Case IPR2016-01020, slip op. at 16 (PTAB Nov. 4, 2016) (Paper 7) (“Cisco Dec.”).

III. INSTITUTION OF *INTER PARTES* REVIEW

The Petition in this proceeding asserts the same grounds of unpatentability as the ones on which we instituted review in the Cisco IPR. *Compare* Pet. 11–53, *with* Cisco Dec. 16. Indeed, Petitioner contends that the Petition asserts only the grounds that the Board instituted in the Cisco IPR, there are no new arguments for the Board to consider, and the Petitioner relies on the same exhibits and expert declaration as in the Cisco IPR. Mot. 5.

For the same reasons set forth in our institution decision in the Cisco IPR, we determine that the information presented in Dish’s Petition shows a reasonable likelihood that Petitioner would prevail in showing that (a) claims 1–3, 7–9, 13–16, and 20–22 would have been obvious over Shively and Stopler and (b) claims 4–6, 10–12, 17–19, and 23–25 would have been

---

[1] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) (“Shively”).
[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) (“Stopler”).
[3] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) (“Gerszberg”).

obvious over Shively, Stopler, and Gerszberg. *See* Cisco Dec. 6–16. Accordingly, we institute an *inter partes* review on the same grounds as the ones on which we instituted review in the Cisco IPR. We do not institute *inter partes* review on any other grounds.

IV. GRANT OF MOTION FOR JOINDER

The Petition and Motion for Joinder in this proceeding were accorded a filing date of November 11, 2016. *See* Paper 4. Thus, Petitioner's Motion for Joinder is timely because joinder was requested no later than one month after the institution date of the Cisco IPR, i.e., November 4, 2016. *See* 37 C.F.R. § 42.122(b).

The statutory provision governing joinder in *inter partes* review proceedings is 35 U.S.C. § 315(c), which reads:

> If the Director institutes an inter partes review, the Director, in his or her discretion, may join as a party to that inter partes review any person who properly files a petition under section 311 that the Director, after receiving a preliminary response under section 313 or the expiration of the time for filing such a response, determines warrants the institution of an *inter partes* review under section 314.

A motion for joinder should (1) set forth reasons why joinder is appropriate; (2) identify any new grounds of unpatentability asserted in the petition; (3) explain what impact (if any) joinder would have on the trial schedule for the existing review; and (4) address specifically how briefing and discovery may be simplified. *See Kyocera Corp. v. Softview LLC*, Case IPR2013-00004, slip op. at 4 (PTAB Apr. 24, 2013) (Paper 15).

As noted, the Petition in this case asserts the same unpatentability ground on which we instituted review in the Cisco IPR. *See* Mot. 5. Dish also relies on the same prior art analysis and expert testimony submitted by

the Cisco Petitioner. *See id.* Indeed, the Petition is nearly identical to the petition filed by the Cisco Petitioner with respect to the grounds on which review was instituted in the Cisco IPR. *See id.* Thus, this *inter partes* review does not present any ground or matter not already at issue in the Cisco IPR.

If joinder is granted, Dish anticipates participating in the proceeding in a limited capacity absent termination of Cisco Petitioner as a party. *Id.* at 6. Dish agrees to "assume a limited 'understudy' role" and "would only take on an active role if Cisco were no longer a party to the IPR." *Id.* Dish further represents that it "presents no new grounds for invalidity and its presence in the proceedings will not introduce any additional arguments, briefing or need for discovery." *Id.* Because Dish expects to participate only in a limited capacity, Dish submits that joinder will not impact the trial schedule for the Cisco IPR. *Id.* at 5–6.

We agree with Petitioner that joinder with the Cisco IPR is appropriate under the circumstances. Accordingly, we *grant* Petitioner's Motion for Joinder.

V. ORDER

Accordingly, it is:

ORDERED that an *inter partes* review is instituted in IPR2017-00254;

FURTHER ORDERED that the Motion for Joinder with IPR2016-01020 is *granted*, and DISH Network, L.L.C. is joined as a petitioner in IPR2016-01020;

FURTHER ORDERED that IPR2017-00254 is terminated under 37 C.F.R. § 42.72, and all further filings shall be made only in IPR2016-01020;

FURTHER ORDERED that, subsequent to joinder, the grounds for trial in IPR2016-01020 remain unchanged;

FURTHER ORDERED that, subsequent to joinder, the Scheduling Order in place for IPR2016-01020 (Paper 8) remains unchanged;

FURTHER ORDERED that in IPR2016-01020, the Cisco Petitioner and Dish will file each paper, except for a motion that does not involve the other party, as a single, consolidated filing, subject to the page limits set forth in 37 C.F.R. § 42.24, and shall identify each such filing as a consolidated filing;

FURTHER ORDERED that for any consolidated filing, if Dish wishes to file an additional paper to address points of disagreement with the Cisco Petitioner, Dish must request authorization from the Board to file a motion for additional pages, and no additional paper may be filed unless the Board grants such a motion;

FURTHER ORDERED that the Cisco Petitioner and Dish shall collectively designate attorneys to conduct the cross-examination of any witness produced by Patent Owner and the redirect of any witness produced by the Cisco Petitioner and Dish, within the timeframes set forth in 37 C.F.R. § 42.53(c) or agreed to by the parties;

FURTHER ORDERED that the Cisco Petitioner and Dish shall collectively designate attorneys to present at the oral hearing, if requested and scheduled, in a consolidated argument;

FURTHER ORDERED that the case caption in IPR2016-01020 shall be changed to reflect joinder of Dish as a petitioner in accordance with the attached example; and

FURTHER ORDERED that a copy of this Decision shall be entered into the record of IPR2016-01020.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC. and DISH NETWORK, LLC,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, has been joined as a petitioner in this proceeding.

Trials@uspto.gov
571-272-7822

Paper 15
Entered: April 3, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2017-00418
Patent 9,014,243 B2

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

DESHPANDE, *Administrative Patent Judge*.

DECISION
Institution of *Inter Partes* Review
37 C.F.R. § 42.108

Petitioner's Motion for Joinder
37 C.F.R. § 42.122(b)

I. INTRODUCTION

Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. (collectively "Petitioner") filed a Petition for *inter partes* review of claims 1–25 of U.S. Patent No. 9,014,243 B2 (Ex. 1001, "the '243 patent"). Paper 1 ("Pet."). Concurrently with its Petition, Petitioner filed a Motion for Joinder with *Cisco Systems, Inc. v. TQ Delta, LLC*, Case IPR2016-01020 ("the Cisco IPR"). Paper 3 ("Mot."). Petitioner represents that the petitioners in the Cisco IPR—Cisco Systems, Inc. and DISH Network, L.L.C.[1]—do not oppose the Motion for Joinder. Mot. 1. TQ Delta, LLC ("Patent Owner") submits that it does not oppose joinder. *See* Paper 7. Patent Owner also elected to waive its Preliminary Response. *Id*.

For the reasons explained below, we institute an *inter partes* review of claims 1–25 of the '243 patent and grant Petitioner's Motion for Joinder.

II. RELATED PROCEEDINGS

Petitioner and Patent Owner identify several pending judicial matters as relating to the '243 patent. Pet. 2–3; Mot. 2–3; Paper 5, 2–4.

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, has been joined as a petitioner in the Cisco IPR.

In the Cisco IPR, we instituted an *inter partes* review of claims 1–25 of the ’243 patent on the following grounds:

References	Basis	Challenged Claims
Shively[2] and Stopler[3]	§ 103(a)	1–3, 7–9, 13–16, and 20–22
Shively, Stopler, and Gerszberg[4]	§ 103(a)	4–6, 10–12, 17–19, and 23–25

Cisco Systems, Inc. v. TQ Delta, LLC, Case IPR2016-01020, slip op. at 16 (PTAB Nov. 4, 2016) (Paper 7) (“Cisco Dec.”).

III. INSTITUTION OF *INTER PARTES* REVIEW

The Petition in this proceeding asserts the same grounds of unpatentability as the one on which we instituted review in the Cisco IPR. *Compare* Pet. 12–55, *with* Cisco Dec. 16. Indeed, Petitioner contends that the Petition asserts only the grounds that the Board instituted in the Cisco IPR, there are no new arguments for the Board to consider, and the Petitioner relies on the same exhibits and expert declaration as in the Cisco IPR. Mot. 6.

For the same reasons set forth in our institution decision in the Cisco IPR, we determine that the information presented in the Petition shows a reasonable likelihood that Petitioner would prevail in showing that (a) claims 1–3, 7–9, 13–16, and 20–22 would have been obvious over Shively and Stopler and (b) claims 4–6, 10–12, 17–19, and 23–25 would have been

[2] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011) (“Shively”).
[3] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012) (“Stopler”).
[4] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013) (“Gerszberg”).

obvious over Shively, Stopler, and Gerszberg. *See* Cisco Dec. 6–16. Accordingly, we institute an *inter partes* review on the same grounds as the ones on which we instituted review in the Cisco IPR. We do not institute *inter partes* review on any other grounds.

IV. GRANT OF MOTION FOR JOINDER

The Petition and Motion for Joinder in this proceeding were accorded a filing date of December 5, 2016. *See* Paper 4. Thus, Petitioner's Motion for Joinder is timely because joinder was requested no later than one month after the institution date of the Cisco IPR, i.e., November 4, 2016.[5] *See* 37 C.F.R. § 42.122(b).

The statutory provision governing joinder in *inter partes* review proceedings is 35 U.S.C. § 315(c), which reads:

> If the Director institutes an inter partes review, the Director, in his or her discretion, may join as a party to that inter partes review any person who properly files a petition under section 311 that the Director, after receiving a preliminary response under section 313 or the expiration of the time for filing such a response, determines warrants the institution of an *inter partes* review under section 314.

A motion for joinder should (1) set forth reasons why joinder is appropriate; (2) identify any new grounds of unpatentability asserted in the petition; (3) explain what impact (if any) joinder would have on the trial schedule for the existing review; and (4) address specifically how briefing and discovery may be simplified. *See Kyocera Corp. v. Softview LLC*, Case IPR2013-00004, slip op. at 4 (PTAB Apr. 24, 2013) (Paper 15).

[5] Because December 4, 2016 fell on a Sunday, the one-month date extended to the next business day, December 5, 2016. *See* 37 C.F.R. § 1.7.

As noted, the Petition in this case asserts the same unpatentability grounds on which we instituted review in the Cisco IPR. *See* Mot. 6. Petitioner also relies on the same prior art analysis and expert testimony submitted by the Cisco Petitioner. *See id.* Indeed, the Petition is nearly identical to the petition filed by the Cisco Petitioner with respect to the grounds on which review was instituted in the Cisco IPR. *See id.* Thus, this *inter partes* review does not present any ground or matter not already at issue in the Cisco IPR.

If joinder is granted, Petitioner anticipates participating in the proceeding in a limited capacity absent termination of Cisco Petitioner as a party. *Id.* at 7. Petitioner agrees to "assume a limited 'understudy' role" and "would only take on an active role if Cisco were no longer a party to the IPR." *Id.* Petitioner further represents that it "presents no new grounds for invalidity and its presence in the proceedings will not introduce any additional arguments, briefing or need for discovery." *Id.* Because Petitioner expects to participate only in a limited capacity, Petitioner submits that joinder will not impact the trial schedule for the Cisco IPR. *Id.* at 6–7.

We agree with Petitioner that joinder with the Cisco IPR is appropriate under the circumstances. Accordingly, we *grant* Petitioner's Motion for Joinder.

V. ORDER

Accordingly, it is:

ORDERED that an *inter partes* review is instituted in IPR2017-00418;

FURTHER ORDERED that the Motion for Joinder with IPR2016-01020 is *granted*, and Comcast Cable Communications, L.L.C., Cox

Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. are joined as a petitioner in IPR2016-01020;

FURTHER ORDERED that IPR2017-00418 is terminated under 37 C.F.R. § 42.72, and all further filings shall be made only in IPR2016-01020;

FURTHER ORDERED that, subsequent to joinder, the grounds for trial in IPR2016-01020 remain unchanged;

FURTHER ORDERED that, subsequent to joinder, the Scheduling Order in place for IPR2016-01020 (Paper 8) remains unchanged;

FURTHER ORDERED that in IPR2016-01020, the Cisco Petitioner and Petitioner will file each paper, except for a motion that does not involve the other party, as a single, consolidated filing, subject to the page limits set forth in 37 C.F.R. § 42.24, and shall identify each such filing as a consolidated filing;

FURTHER ORDERED that for any consolidated filing, if Petitioner wishes to file an additional paper to address points of disagreement with the Cisco Petitioner, Petitioner must request authorization from the Board to file a motion for additional pages, and no additional paper may be filed unless the Board grants such a motion;

FURTHER ORDERED that the Cisco Petitioner and Petitioner shall collectively designate attorneys to conduct the cross-examination of any witness produced by Patent Owner and the redirect of any witness produced by the Cisco Petitioner and Petitioner, within the timeframes set forth in 37 C.F.R. § 42.53(c) or agreed to by the parties;

FURTHER ORDERED that the Cisco Petitioner and Petitioner shall collectively designate attorneys to present at the oral hearing, if requested and scheduled, in a consolidated argument;

FURTHER ORDERED that the case caption in IPR2016-01020 shall be changed to reflect joinder of Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. as a petitioner in accordance with the attached example; and

FURTHER ORDERED that a copy of this Decision shall be entered into the record of IPR2016-01020.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

---

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

Paper No. __

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,[1]

v.

TQ DELTA, LLC,
Patent Owner.

IPR No. IPR2016-01020
U.S. Patent No. 9,014,243

PETITIONER'S REPLY

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[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

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Petitioner's Exhibit List

June 8, 2016

Ex.	1001	U.S. Patent No. 9,014,243 to Tzannes ("the '243 patent")
Ex.	1002	Prosecution File History of U.S. Pat. No. 9,014,243
Ex.	1003	Prosecution File History of U.S. Pat. No. 8,355,427
Ex.	1004	Prosecution File History of U.S. Pat. No. 8,218,610
Ex.	1005	Prosecution File History of U.S. Pat. No. 8,073,041
Ex.	1006	Prosecution File History of U.S. Pat. No. 7,292,627
Ex.	1007	Prosecution File History of U.S. Pat. No. 6,961,369
Ex.	1008	U.S. Provisional Application No. 60/164,134
Ex.	1009	Declaration of Dr. Jose Tellado under 37 C.F.R. § 1.68
Ex.	1010	Curriculum Vitae of Dr. Jose Tellado
Ex.	1011	U.S. Patent No. 6,144,696 to Shively et al. ("Shively")
Ex.	1012	U.S. Patent No. 6,625,219 to Stopler ("Stopler")
Ex.	1013	U.S. Patent No. 6,424,646 to Gerszberg et al. ("Gerszberg")
Ex.	1014	Harry Newton, NEWTON'S TELECOM DICTIONARY, 13th Ed. (1998) (selected pages)
Ex.	1015	Kim Maxwell, "Asymmetric Digital Subscriber Line: Interim Technology for the Next Forty Years," *IEEE Communications Magazine* (Oct. 1996).
Ex.	1016	Walter Goralski, ADSL AND DSL TECHNOLOGIES (McGraw-Hill 1998) (selected pages)
Ex.	1017	American National Standard for Telecommunications, Network and Customer Installation Interfaces—Asymmetric Digital Subscribers Line (ADSL) Metallic Interface (ANSI T1.413-1995)

Ex. 1018	*Intentionally omitted*
Ex. 1019	*Intentionally omitted*
Ex. 1020	*Intentionally omitted*
Ex. 1021	Fig. 6 from Ex. 2009 (T. Regan, "ADSL Line Driver/Receiver Design Guide, Part 1" (February 2000)).
Ex. 1022	Robert T. Short, "Physical Layer," *in* WIMEDIA UWB (2008).
Ex. 1023	Denis J. G. Mestdagh and Paul M. P. Spruyt, "A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions of Communications*, Vol. 44, No. 10, (October 1996).
Ex. 1024	Stefan H. Muller and Johannes B. Huber, "A Comparison of Peak Power Reduction Schemes for OFDM," IEEE Global Telecommunications Conference (1997).
Ex. 1025	Jose Tellado-Mourelo, "Peak to Average Power Reduction for Multicarrier Modulation," A dissertation submitted to the Department of Electrical Engineering and the Committee on Graduate Studies of Stanford University (Sept. 1999)
Ex. 1026	Second Declaration of Dr. Jose Tellado under 37 C.F.R. § 1.68
Ex. 1027	Deposition Transcript of Dr. Robert T. Short
Ex. 1028	T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected pages).
Ex. 1029	Abe, RESIDENTIAL BROADBAND (2000) (selected pages).
Ex. 1030	Mohamed Zekri, et al., "DMT Signals with Low Peak-to-Average Power Ratio," *Proceedings of the IEEE International Symposium on Computers and Communications* (held July 6-8, 1999).
Ex. 1031	Second Declaration of David Bader
Ex. 1032	Peter S. Chow, et al., "A Practical Discrete Transceiver Loading Algorithm for Data Transmission over Spectrally Shaped Channels," *IEEE Transactions on Communications*, Vol. 43, No. 2/3/4 (1995).

Ex. 1033	Kamran Sistanizadeh, et al., "Multi-Tone Transmission for Asymmetric Digital Subscriber Lines (ADSL)", *Communications, 1993. ICC '93 Geneva. Technical Program, Conference Record, IEEE International Conference* (held May 23-26, 1993).
Ex. 1034	ADSL transmitter simulation program by Dr. Tellado

I. Summary

Patent Owner TQ Delta raises various arguments, but they are all severely flawed, whether by a misinterpretation of the prior art or a misunderstanding of the technology involved. The obviousness rationale for combining Shively and Stopler derives almost entirely from a POSITA’s straightforward consideration of undisputed facts. The only substantive limitation in dispute—“scrambling”—is plainly taught by Stopler, which even uses the same “scrambling” terminology to describe the concept. Accordingly, the Board should issue a Final Written Decision holding all claims of the ’243 patent unpatentable for obviousness.

II. Claim Construction

A. “scrambling…a plurality of carrier phases”

TQ Delta proposes construing the phrase “scrambling…a plurality of carrier phases” to mean “adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts.” Resp., pp.14-19.

The “scrambling” phrase does not need construction, since the prior art relied upon—Stopler—uses the same “phase scrambling” terminology to describe pseudo-random phase changes. CSCO-1012, 12:24-31. Accordingly, the Board should not adopt TQ Delta’s proposed construction.

B. “transceiver”

TQ Delta notes that a district court—which applies a different claim

interpretation standard—adopted a different claim construction for "transceiver." Resp., pp.13-14. But TQ Delta does not show any error in the Board's currently-adopted construction. Accordingly, there is no reason for the Board to modify its construction.

III. Combining the teachings of Shively and Stopler would have been obvious to a POSITA

TQ Delta argues that it would not have been obvious to combine the DSL technologies of Shively and Stopler. Resp., pp.45-47. TQ Delta further alleges that Cisco's obviousness rationale suffers from hindsight bias. *Id.*, p.49. But the obviousness rationale is based on agreed-upon facts and common engineering sense. As discussed further below, there is no dispute that:

- multicarrier communication systems generate signals with a high peak-to-average power ratio (PAR), which is undesirable;
- repeating the same bits on multiple carriers, the technique taught in Shively, increases PAR;
- scrambling the phases of individual signal carriers was a known technique for reducing PAR; and
- Stopler teaches a phase scrambler.

In light of these facts, a POSITA would have found it obvious to incorporate a phase scrambler—like that in Stopler—into Shively's system to counteract the increase in PAR caused by Shively's bit spreading technique. CSCO-1009, ¶¶67-

68. Rather than hindsight, the combination would have been a straightforward application of ordinary engineering sense to basic facts known to a POSITA. CSCO-1009, ¶¶18, 67-68.

A. DMT-based communications systems were known to be susceptible to challenges caused by signals with high PAR

There is no dispute that multicarrier systems using discrete multitone ("DMT") technology faced issues relating to signals with a high peak-to-average ratio ("PAR"). *See* TQ-2003, ¶¶20-22. Similarly, there is no dispute that signals with high PAR can induce clipping in the transmitter circuitry. *See* TQ-2003, ¶¶24-25, 30. These facts are succinctly stated in the ANSI T1.413-1995 standard:

> A DMT time-domain signal ***has a high peak-to-average ratio*** (its amplitude distribution is almost Gaussian), and ***large values may be clipped*** by the digital-to-analog converter.

CSCO-1017, §6.5 (p. 36).

Cisco's expert, Dr. Tellado, testified—and TQ Delta has not disputed—that a POSITA would have known such background information:

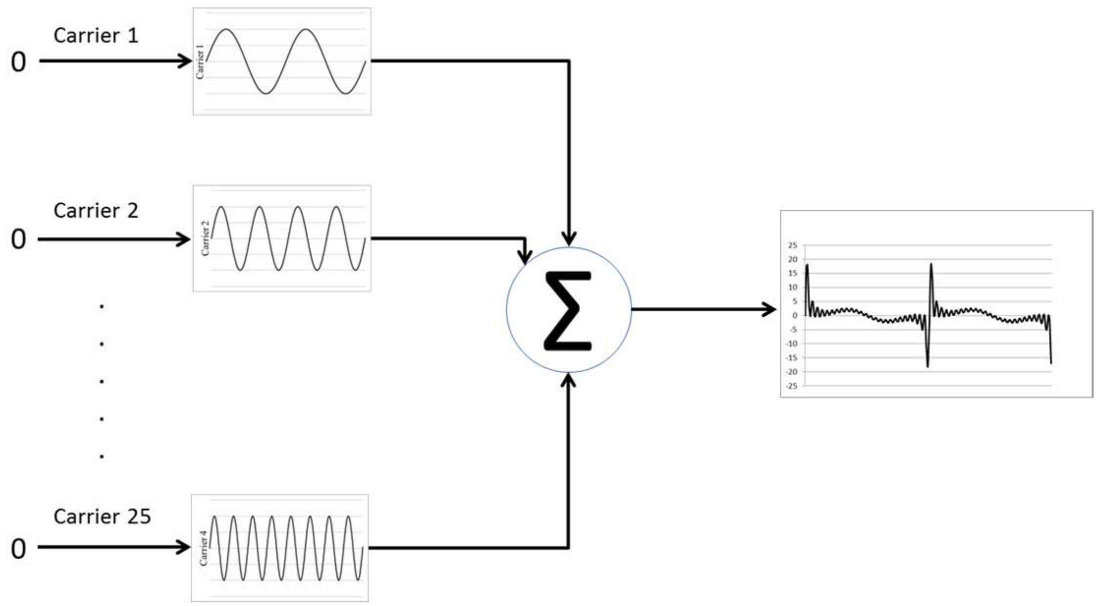
> [A]n understanding of the '243 patent requires an appreciation of digital communications using discrete multitone (DMT) signals, and appreciation for the potential for such multicarrier signals to have a high peak-to-average ratio, causing clipping during transmission. Such knowledge would be within the level of skill in the art.

CSCO-1009, ¶20.

The parties also agree that engineers knew that one way to reduce the likelihood of clipping was to design transmitters to handle a greater dynamic range. TQ-2003, ¶26. But it was also known that such transmitters were more expensive, less efficient, consumed more electricity, and generated more heat. TQ-2003, ¶26; CSCO-1027, 45:21-46:6. Thus, engineers would have sought out other techniques to reduce PAR. CSCO-1027, 46:23-47:3.

B. Transmitting the same data on multiple carriers causes a spike in signal amplitude and increases PAR

There is no dispute that when many carriers of a multicarrier signal have the same phase, the result is a signal with "large spikes in amplitude and, therefore, a high PAR." TQ-2003, ¶22. TQ Delta acknowledged that high PAR occurs "where the same bit or bits is/are purposely sent in a redundant manner on multiple carriers." Resp., pp.6-7; TQ-2003, ¶22; CSCO-1027, 97:13-15. As TQ Delta's declarant Dr. Short illustrated in the figure below, when the signal carriers carry the same bits, they have the same phases, which add coherently to create a transmission signal with a large spike in amplitude. TQ-2003, ¶22. TQ Delta admitted that such signal has a "high PAR." Resp., p.7.



TQ-2003, ¶18.

C. Shively transmits the same data on multiple carriers, which increases PAR

In Shively's system the same bits are purposely sent in a redundant manner on multiple carriers, which TQ Delta admits leads to high PAR.[2] CSCO-1011, 11:17-18; Resp., p.10; CSCO-1027, 9:7-10. Because the same data (Shively's "k-bit symbol") is modulated on multiple carriers, the carriers will phase align and will add coherently to create a transmission signal with a spike in amplitude

[2] Elsewhere TQ Delta argues that Shively does not suffer from increased PAR (Resp., pp.47-49), but that argument is based on an erroneous analysis of a hypothetical 18,000-foot ADSL line. TQ Delta and its expert repeatedly concede that Shively transmits the same data on multiple carriers, which increases PAR. Resp., pp.10; TQ-2003, ¶22; CSCO-1027, 96:16-20, 97:10-15, 100:4-7.

(power). TQ-2003, ¶ 22; CSCO-1027, 97:21-23. This spike would not have occurred without Shively's technique, since the carriers would have been deemed unusable, and no data would have been transmitted on those carriers. CSCO-1026, ¶6. Thus, Shively's technique creates new amplitude spikes in the multicarrier signal and causes an increase in PAR. *Id*.; Resp., pp.6-7.

D. Phase scrambling was a known technique for reducing PAR

A POSITA would have known that one way to reduce PAR is to scramble phases of individual carriers. As Dr. Tellado stated, "phase scrambling was probably the most popular way" to reduce PAR. TQ-2002, 100:9-13; CSCO-1027, 9:11-13 ("just by rotating the symbols, then you can reduce the peak-to-average ratio.").

Prior art technical publications confirm that phase scrambling was a known way to reduce PAR. A 1996 article notes the use of "discrete multitone (DMT) modulation technique … for applications [such as] asymmetric digital subscriber line (ADSL)." CSCO-1023, p.1234; CSCO-1031, ¶2. The article describes prior efforts "to reduce the peak-to average power ratio of the DMT signal," and proposes a technique in which "the phasor of each QAM-modulated carrier is changed by means of a fixed phasor-transformation," such as a "random phasor transformation." CSCO-1023, p.1234-35. Dr. Short agreed that such phasor transformations include phase scrambling. CSCO-1027, 77:18-20.

Another 1997 article notes that "it is highly desirable to reduce the PAR" of a multicarrier signal. CSCO-1024, p.1; CSCO-1031, ¶3. To do so, the article describes a transmitter that "constructs its transmit signal with low PAR by coordinated addition of appropriately ***phase rotated signal parts***" where the signal parts are subcarriers within a multicarrier vector. CSCO-1024, p.1. This technique was applied to DMT systems, where the DMT tones (carriers) had a "phase rotation applied to each tone." CSCO-1028, p.238; CSCO-1031, ¶7.

Thus, prior to November 9, 1999 (the earliest claimed priority date of the '243 Patent), multiple engineers working with DMT-based systems had written about the use of phase scrambling to reduce PAR. These articles support and reinforce Dr. Tellado's opinion that a POSITA would have been familiar with phase scrambling as a known technique for reducing PAR. CSCO-1009, ¶67; CSCO-1026, ¶54.

TQ Delta presents no evidence to the contrary. While, TQ Delta's declarant Dr. Short agreed that randomizing phases of individual carriers is a way to reduce PAR, he pointedly declined to provide any opinion regarding the fact that phase scrambling was known in the prior art. CSCO-1027, 50:3-8, 51:4-11.

Thus, all of the evidence of record supports the unchallenged conclusion that a POSITA in the prior art timeframe would have been familiar with phase scrambling as a technique for reducing PAR in DMT systems.

E. Combining Stopler's phase scrambler with Shively's transmitter is merely the use of a known technique to improve a similar device.

TQ Delta argues that Cisco failed to sufficiently explain how the Shively and Stopler combination is the use of a known technique to improve a similar device in the same way. Resp., pp.45-47. Instead, TQ Delta argues that Cisco used hindsight bias to make the combination. Resp., pp.49-50. These assertions are unfounded.

First, the Petition unambiguously identified the "known technique" as Stopler's use of a phase scrambler to randomize the phases of subcarriers, which improves (reduces) PAR. Pet., p.14.

Second, the Petition explains that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." Pet., p.15. Thus, in the combination, the phase scrambler improves Shively's transmitter (by reducing PAR) in the same, known way that the phase scrambler improves Stopler's transmitter.

Finally, the Petition explains that Shively and Stopler describe similar devices, specifically, "multicarrier communications apparatuses, such as modems." Pet., p.17.

Thus, the combination is merely the use of a known technique (phase scrambling) to improve a similar device (multicarrier modem) in the same way (to

reduce PAR). CSCO-1009, ¶¶ 62-70.

F. Market forces would have prompted a POSITA to combine Shively and Stopler

TQ Delta argues that there were no "market forces" to prompt the combination of Shively's and Stopler's techniques." Resp., pp.55-57.

But the most basic of market forces—cost—was recognized at the time as influencing the development of multicarrier technology. Multiple engineers wrote of the importance of minimizing cost:

> **Cost** – This is the dominant factor when dealing with consumer markets.

CSCO-1029, p.70; CSCO-1031, ¶8.

> ***Success of a service*** (and its underlying technology) ***depends greatly on its price*** and its relation to available alternatives. Service price, in turn, depends greatly on the cost of equipment and labor costs for operation…. A recurring theme in the field of DSLs is that the cost of additional capability in the transceiver yields greater savings from reduced operating costs, greater loop reach, or possible additional applications.

CSCO-1028, p.17.

As Dr. Short admitted, an increase in PAR is associated with more expensive communication equipment. CSCO-1027, 45:15-46:12. The drive to reduce equipment costs would have motivated a POSITA to include Stopler's

phase scrambler in Shively's transmitter to reduce PAR. CSCO-1026, ¶54. Thus, combining Shively and Stopler would have been obvious for this additional reason.

IV. Stopler's phase scrambler reduces PAR because it scrambles phases of individual QAM symbols

TQ Delta argues that Stopler's phase scrambler does not reduce PAR because the phase scrambler is applied to DMT symbols, not to individual QAM symbols. *See* Resp., pp.14-18, 57-59.[3] But TQ Delta's argument is based on an illogical reading of Stopler and undermined by the testimony of its expert.

A. Dr. Short admitted that Stopler's phase scrambler is applied to QAM symbols

Stopler states that "the phase scrambler is applied to all symbols." CSCO-1012, 12:26-27. Dr. Short agreed that in this statement, Stopler refers to phase scrambling *QAM symbols*:

> A. …"However, to simplify implementation, the phase scrambler is applied to all symbols," not just the overhead symbols, so he is implying that he's rotating the entire bank of symbols.…
>
> Q. In that sentence, however, to simplify what you read --
>
> A. Yes.
>
> Q. -- it says it applies to all symbols, right?

[3] A DMT symbol comprises multiple signal carriers, and signal carriers are also referred to as QAM symbols.

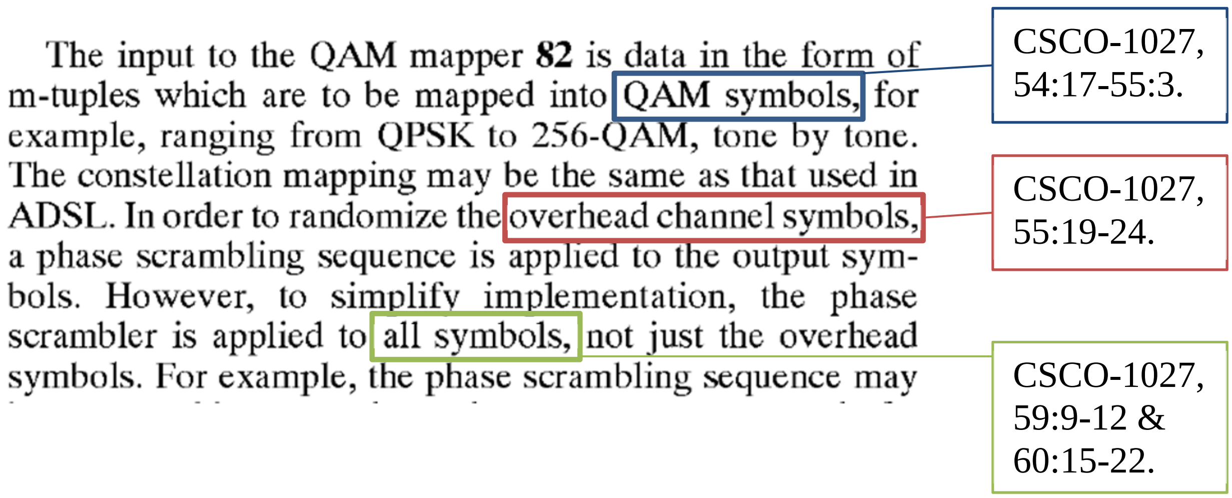
A. Correct.

Q. ***And those symbols are QAM symbols***?

A. ***Correct***.

CSCO-1027, 59:9-12, 60:15-22 (emphasis added).

More broadly, Stopler uses the word "symbol" multiple times in describing the phase scrambler, and Dr. Short agreed that these refer to *QAM symbols*:


The input to the QAM mapper **82** is data in the form of m-tuples which are to be mapped into QAM symbols, for example, ranging from QPSK to 256-QAM, tone by tone. The constellation mapping may be the same as that used in ADSL. In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols. However, to simplify implementation, the phase scrambler is applied to all symbols, not just the overhead symbols. For example, the phase scrambling sequence may

CSCO-1012, 12:20-28 (annotated).

Furthermore, there is no dispute that the input to Stopler's phase scrambler is a sequence of QAM symbols. CSCO-1027, 58:6-8. Thus, there is no dispute that Stopler's phase scrambler takes in QAM symbols and applies phase scrambling to QAM symbols.

B. Stopler does not describe phase scrambling DMT symbols

TQ Delta's argument—that a POSITA would have understood Stopler as teaching the phase scrambling of DMT symbols—is illogical and has no basis in

Stopler's text. Resp., p.34. Indeed, Dr. Short admitted that Stopler does *not* describe applying the phase scrambler to a DMT symbol:

> Q. Well, you would agree with me that [Stopler] doesn't expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

CSCO-1027, 60:11-14.

Stopler states that the purpose of the phase scrambler is to "randomize the overhead channel symbols." CSCO-1012, 12:24. Since overhead channel symbols are QAM symbols (*see* CSCO-1027, 55:19-24), Stopler's intent is to randomize the phases of QAM symbols. Randomizing DMT symbols—as TQ Delta argues—would not achieve Stopler's stated purpose for the phase scrambler. CSCO-1026, ¶57.

The illogic of TQ Delta's argument is further demonstrated by the broader context of the phase scrambler in Stopler's system. CSCO-1026, ¶¶55-58. Stopler contemplates that the phase scrambler and other transmitter components could be used with either a DMT *or* CDMA modulator. CSCO-1012, 12:55-57; *see also* Resp., pp.32-33. Since a CDMA modulator does not employ DMT symbols, there is no reason for Stopler's phase scrambler to operate on DMT symbols. CSCO-1026, ¶58. In contrast, both DMT and CDMA modulators employ QAM symbols. *Id*. Thus the straightforward reading of Stopler—as applying the phase scrambler

to individual QAM symbols—is the only possible reading that is logically and technically coherent. *Id*.

C. Stopler contemplates systems with multiple pilot tones and multiple kinds of overhead channel symbols

TQ Delta argues that Stopler should be understood as phase scrambling DMT symbols because the phase scrambler's purpose is to randomize the overhead channel symbols, and each DMT symbol in the ANSI T1.413-1995 standard has only one pilot tone. Resp., p.40; *see* CSCO-1017, p.46. This argument fails for multiple reasons, including that it ignores the plain text of Stopler.

First, Stopler does not limit overhead channel symbols to a single pilot tone per DMT symbol. Indeed, Stopler refers elsewhere to multiple "pilot ***tones***." CSCO-1012, 12:51-52. Furthermore, Stopler's techniques are not limited to ANSI T1.413-1995 or even DMT, but are applicable to any "particular signal modulation desired." CSCO-1012, 12:56-57. As Dr. Short admitted, other multicarrier technologies can use more than one pilot tone. CSCO-1027, 61:15-18.

Second, pilot tones are just an *example* of overhead symbols. *See* CSCO-1012, 9:62 ("overhead signals, ***such as*** pilot tones") & 12:51-52 ("overhead bits (***e.g.***, pilot tones)") (emphases added). Many other kinds of overhead channel symbols are also possible. For example, the TIE/EIA-95 Standard referenced in Stopler describes multiple overhead channels that include one pilot channel, one sync channel and up to 9 paging channels. TQ-2005, pp.728-729; CSCO-1012,

12:61-63. Thus, the entire logic of TQ Delta's argument is based on the incorrect premise that Stopler assumed that the only overhead would be a single ANSI T1.413-1995 pilot tone.

A POSITA would have understood that data in the overhead channel symbols will probably not be random, but is likely to be highly structured. CSCO-1009, ¶59. In the ANSI T1.413-1995 standard, for example, the bits encoding the pilot tone are held constant at zero. CSCO-1017, p.46. Such non-random, structured data increases the likelihood for phases of carriers to align, thereby increasing PAR. CSCO-1009, ¶59. To break up the structured data, Stopler employs a phase scrambler that scrambles phases of overhead channel symbols, and thereby reduces PAR. CSCO-1009, ¶60; CSCO-1026, ¶¶57-58.

D. TQ Delta's arguments about the '156 patent are moot because it changes the phase of individual QAM symbols

TQ Delta argues that Stopler's phase scrambler operates on DMT symbols because it is implementing a noise-immunity technique described in U.S. 6,370,156. Resp., pp.38-40. This argument fails for several reasons.

First, TQ Delta does not offer any explanation for how Stopler, the inventor, would have learned of the noise-immunity technique in the '156 patent, which was not published before it was granted in 2002. Thus, at the time of the Stopler patent's filing in 1999, the inventor Stopler could not have known of the patent application that resulted in the '156 patent.

Second, the '156 patent does not scramble DMT symbols. Rather, the '156 patent describes sequencing the pilot carrier—and only the pilot carrier—through four different phase values. *See* TQ-2004, 7:5-6, 7:40-45. Dr. Short agreed that the '156 Patent rotates only the phase of the pilot carrier (tone), not the phase of an entire DMT symbol. CSCO-1027, 67:4-9.

Thus, not even the '156 patent describes changing the phase of an entire DMT symbol. Even if Stopler used the '156 patent's technique—and the evidence discussed below suggests that it does not—that fact would still not support TQ Delta's assertion that Stopler's phase scrambler is applied to DMT symbols.

Third, there are significant technical differences between Stopler's phase scrambler and the technique described in the '156 patent. The '156 patent changes the phase of only the pilot carrier. TQ-2004, 7:40-45; CSCO-1027, 67:4-9. Stopler's phase scrambler, however, is applied not just to the pilot tone, but to "all symbols." CSCO-1012, 12:26-28.

Stopler and the '156 patent also differ in their phase rotation sequences. The '156 patent changes its pilot carrier using a repeating sequence of four rotations. TQ-2004, 7:40-45; *see also* CSCO-1027, 76:24-77:5 (explaining that the '156 patent does not require random phase changes). Stopler, on the other hand, uses a "phase scrambling sequence… generated by a pseudo-random generator," making the phase changes effectively random. CSCO-1012, 12:28-29.

Thus, there is virtually no similarity between Stopler's phase scrambler and the '156 patent's technique, and therefore no reason to believe that Stopler's description of the phase scrambler should be read as using ideas from the '156 patent. And even if it were, the '156 patent does not rotate the phase of entire DMT symbols, so there is no reason to disturb the natural reading of Stopler as applying its phase scrambler to QAM symbols.

V. TQ Delta's remaining arguments are without merit

TQ Delta raises a variety of additional arguments, none of which hold up to even moderate scrutiny. Cisco responds to each argument below.

A. Shively's technique is not limited to 18,000 foot cables

In support of its allegation that Shively's technique does not increase PAR, TQ Delta presents a supposed analysis of Shively's PAR for an 18,000 foot cable. Resp., pp.27-29. While that analysis is deeply flawed—as discussed below—the entire premise for looking at an 18,000 foot example is illusory. Shively is not limited to cable lengths of 18,000 feet. Shively merely mentions this length in passing as an example of where "high signal attenuation… is usually observed." CSCO-1011, 9:66-10:1. Notably, the ANSI T1.413-1995 standard defines multiple "test loops," including loops of ten, 6000, 9000, and 12000 feet. CSCO-1017, p.118; TQ-2002, 57:3-4 ("modems have to work with different lengths of loops, not only 18,000 feet").

TQ Delta's attempt to pigeonhole Shively's technique to 18,000-foot cables is also inconsistent with Shively's disclosure. Shively describes its bit-spreading technique as a way to use "impaired parts of the frequency band," and to "compensate for high attenuation ***and/or high noise***" in such impaired subcarriers. CSCO-1011, 15:58-59, 15:50. Dr. Short admitted that other impairments—including crosstalk noise—occur on line lengths of less than 18,000 feet and agreed that Shively's technique could be used on lines with noise-induced impairments. CSCO-1027, 24:8-25:10, 93:11-94:8.

The ANSI T1.413-1995 standard describes crosstalk as potentially significant noise source in an ADSL system. There are many sources of crosstalk and relatively short lines can have significant crosstalk noise. CSCO-1026, ¶7. The ANSI standard provides multiple graphs showing the potential near-end cross talk ("NEXT") noise levels caused by various kinds of adjacent communication lines. As illustrated in the annotated graphs prepared by Dr. Tellado, the NEXT noise levels are above the -140 dBm/Hz background noise floor:

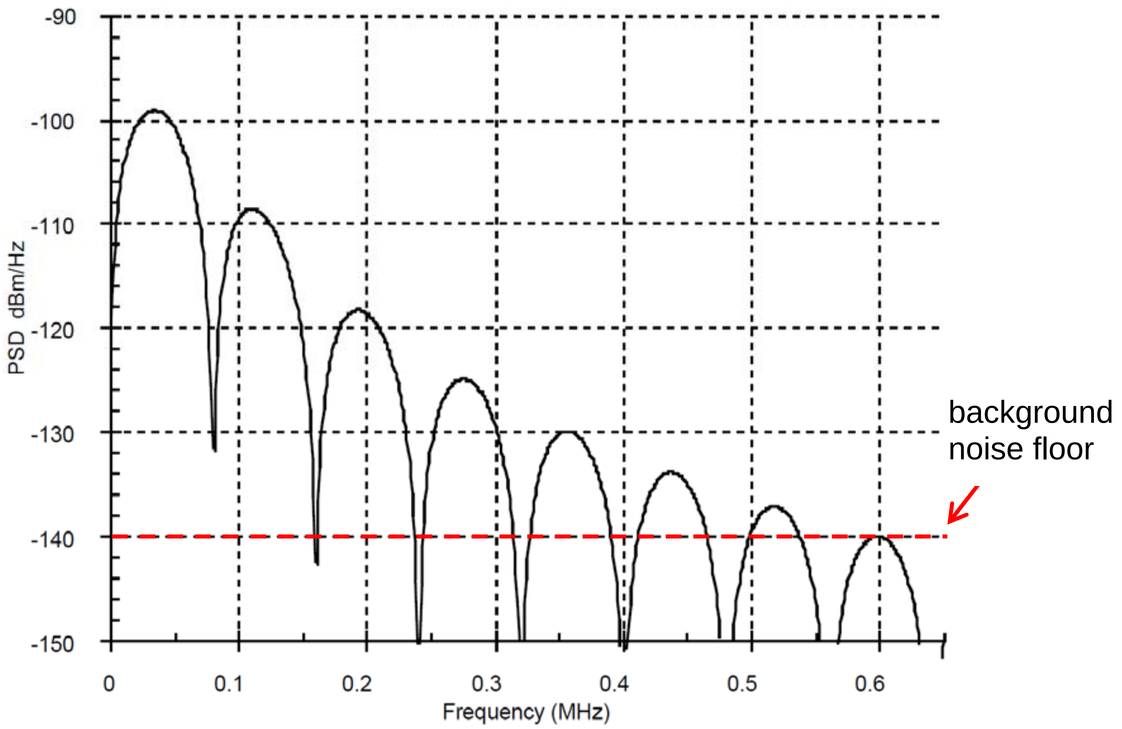


Figure B.1 – 24-disturber DSL NEXT

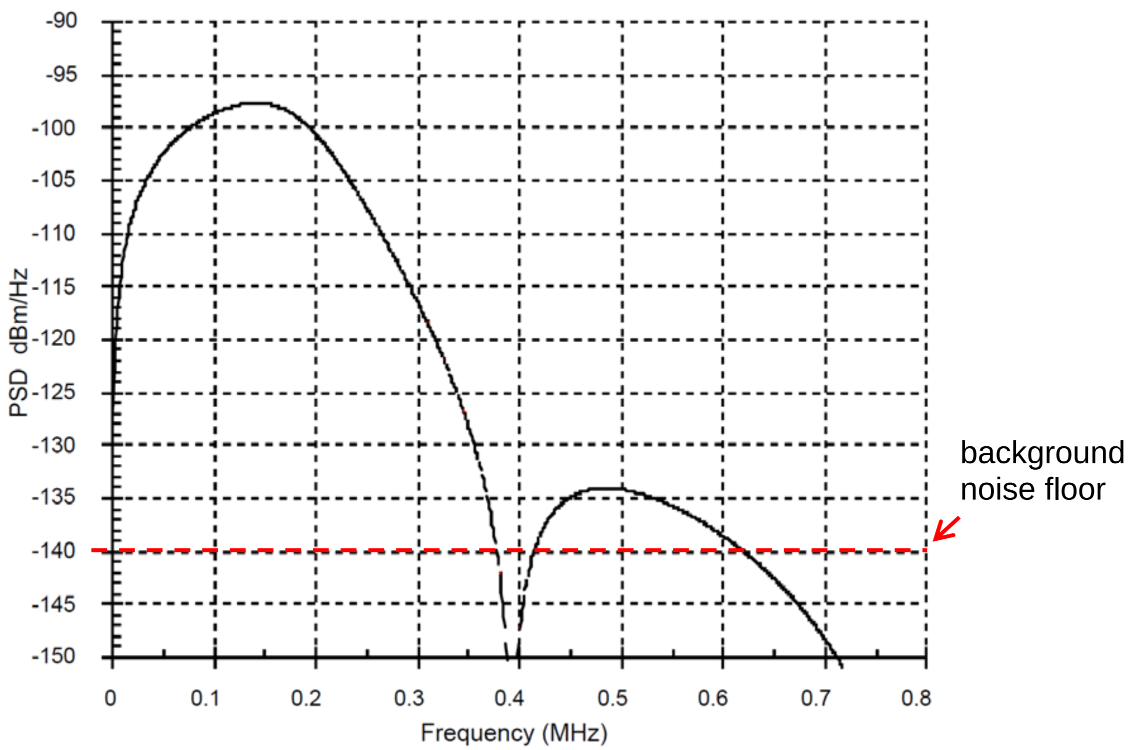


Figure B.2 – 10-disturber HDSL NEXT

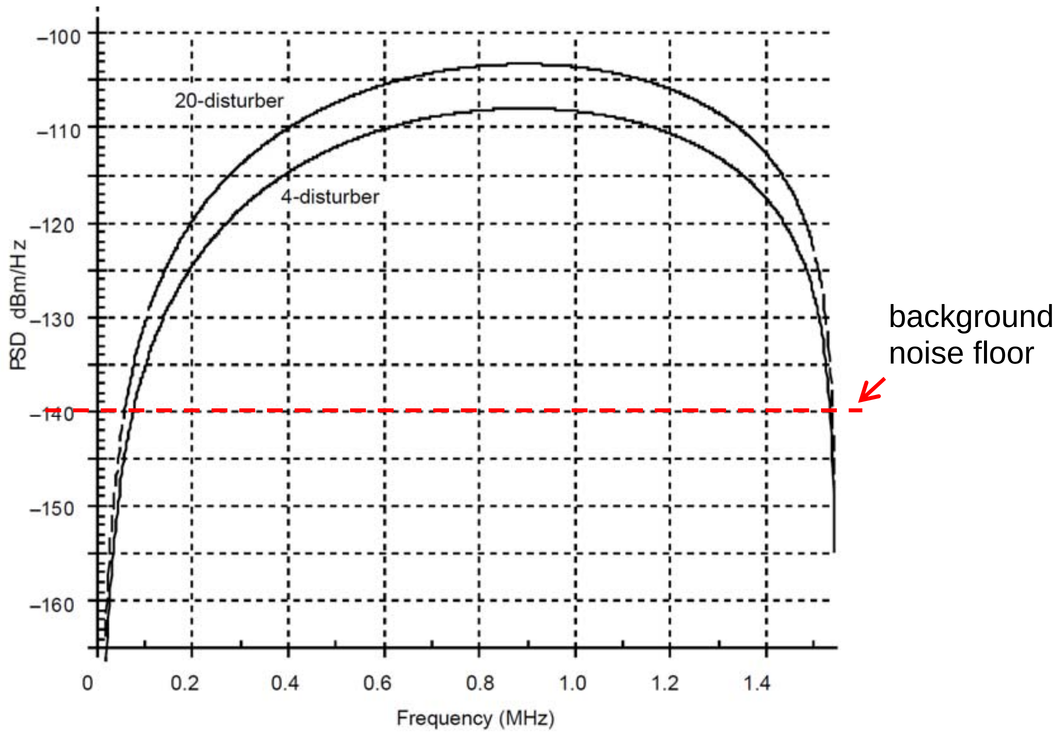


Figure B.3 – 4 and 20-disturber T1 NEXT

CSCO-1026, ¶¶9-11; CSCO-1017, pp.138, 140, 142.

The ANSI T1.413-1995 standard also provides an example graph showing potential far-end crosstalk in an ADSL system:

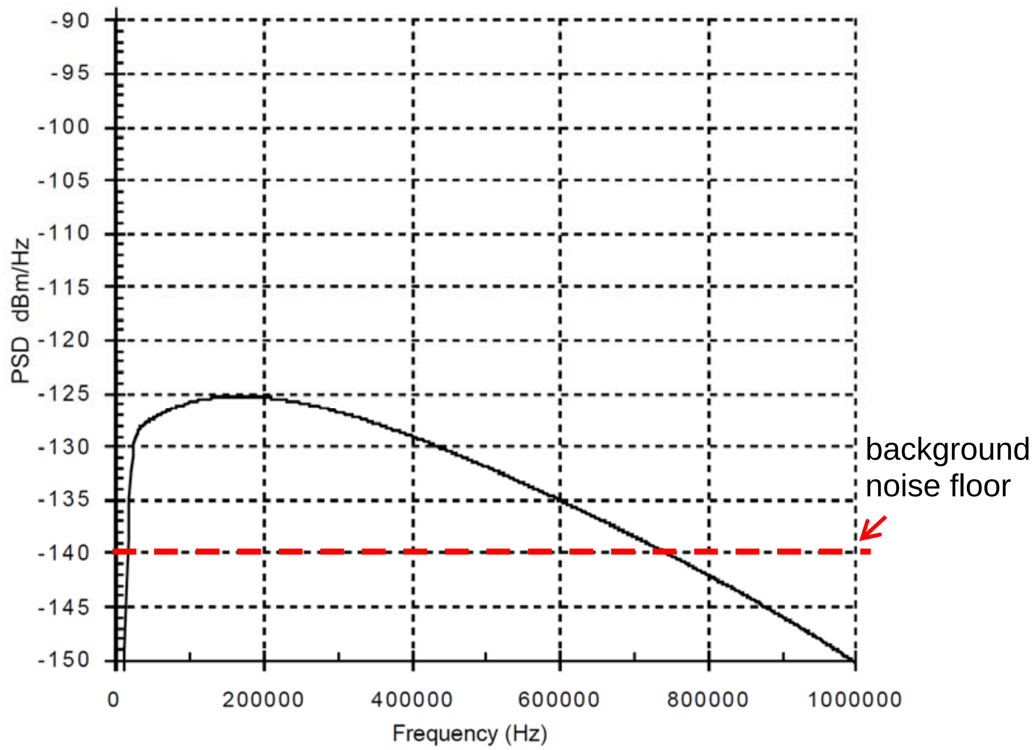


Figure B.4 – Theoretical 10-disturber ADSL FEXT

CSCO-1026, ¶12; CSCO-1017, p.144.

These graphs of crosstalk noise levels show that crosstalk noise can be a significant line impairment, with the crosstalk noise exceeding the -140 dB/Hz background noise level. CSCO-1026, ¶13. Because crosstalk can be significant on even short lines, Shively's technique could be usefully applied to any line length. CSCO-1026, ¶14. Accordingly, there is no basis for TQ Delta's attempt to limit Shively's technique to only 18,000-foot cables.

B. Dr. Short's analysis of a hypothetical 18,000 foot cable is flawed

Because Shively's technique is not limited to 18,000 foot cables, the entire premise of Dr. Short's supposed analysis of such an example is baseless. Further,

Dr. Short makes fundamentally incorrect assumptions that render his results untrustworthy and meaningless.

Specifically, Dr. Short assumes that a multicarrier signal is approximately Gaussian, *even when bits are repeated on multiple carriers*. TQ-2003, ¶66. This is a fundamental engineering error, since the Gaussian approximation only holds when the phases of the individual carriers are random. CSCO-1026, ¶16; CSCO-1030, p.362 ("The amplitude distribution of a DMT signal ***with random input data*** is approximately Gaussian for large number of carriers."); CSCO-1031, ¶4; CSCO-1001, 1:52-55. Shively's technique breaks that assumption because the subcarriers used for bit-spreading are no longer randomized; instead, they are purposely set to the same phase.

Because a system employing Shively's technique does not have carriers with random phases, the signals produced by such a system cannot be reasonably approximated by a Gaussian random variable. CSCO-1026, ¶16. The following examples demonstrate this fact and illustrate the enormous errors that resulted from Dr. Short's use of the approximation.

1. Likelihood of phase alignment for random data

In a multicarrier signal transmitting random data, the phase of each subcarrier is essentially random. If two carriers are phase-modulated with one bit per subcarrier, the likelihood of both bits being equal—and the carriers having the

same phase—is 2 in 4:

Bit #1	Bit #2	Phases Aligned?
0	**0**	**Aligned**
0	1	Not aligned
1	0	Not aligned
1	**1**	**Aligned**

Thus, if the first and second bits are random, the likelihood of the subcarriers having the same phase is 50%. CSCO-1026, ¶18.

With three bits of data on three subcarriers, there are eight possible combinations of values. Again, there are only two possible combinations where all bits have the same value and all phases align:

Bit #1	Bit #2	Bit #3	Phases Aligned?
0	**0**	**0**	**Aligned**
0	0	1	Not aligned
0	1	0	Not aligned
0	1	1	Not aligned
1	0	0	Not aligned
1	0	1	Not aligned
1	1	0	Not aligned

1	**1**	**1**	**Aligned**

Thus, if the bits are transmitted are random, then the likelihood of all three subcarriers having the same phase is 2 in 8, or 25%. CSCO-1026, ¶19.

These examples can be continued to greater numbers of bits. With four bits, the likelihood of four subcarriers having the same phase is 2 in 16, or 12.5%. CSCO-1026, ¶20. With 8 bits, the likelihood is 2 in 256, or 0.78%. CSCO-1026, ¶21. Generally, the likelihood of *n* subcarriers transmitting *n* random bits all having the same phase is:

$$\frac{2}{2^n} \qquad \text{Eq. 1}$$

CSCO-1026, ¶22.

2. Likelihood of phase alignment using Shively's bit-spreading technique

Shively's technique significantly changes the likelihood of multiple carriers having the same phase because the carriers' phases are no longer independent of one another. Instead, multiple carriers are purposely modulated with the same bit, and thus they have the same phase. Shively suggests using groups of 4 carriers. CSCO-1011, 13:49-52. Thus, all 4 carriers in a group employing Shively's technique will have the same phase. Their likelihood of phase alignment is 100%—a stark contrast to the 12.5% chance if those 4 carriers were independent of

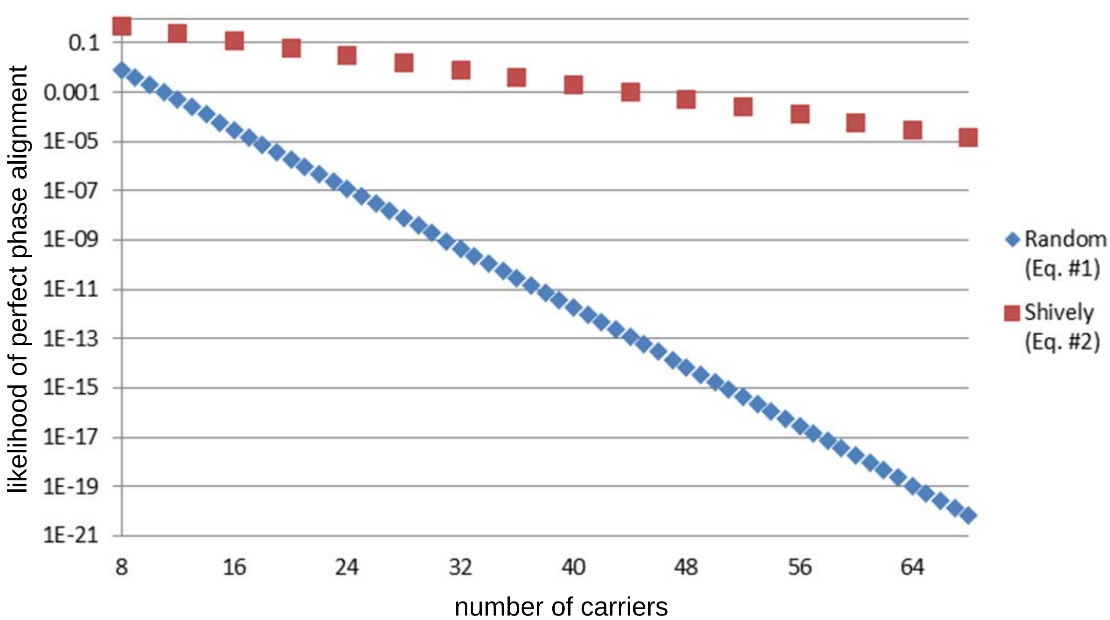
one another. CSCO-1026, ¶24. If 8 carriers use Shively's technique (two groups of 4), the likelihood of all 8 carriers being phase-aligned is 50%; again this is in stark contrast to the 0.78% chance if those carriers had uncorrelated, random phases. *Id*. In general, the likelihood of *n* carriers all having the same phase if they are employing Shively's technique is:

$$\frac{2}{2^{\left(\frac{n}{4}\right)}} \qquad \text{Eq. 2}$$

CSCO-1026, ¶25.

3. Comparing the phase-alignment likelihoods for Shively's technique and random data

Graphing equations 1 and 2 shows that they are never very close, and they only grow farther apart as the number of subcarriers increases:



CSCO-1026, ¶26.

Thus, the probability of multiple subcarriers having their phases aligned is

radically different between the random-data case and Shively's technique. The enormity of the differences is also apparent when considering how frequently a given number of carriers will be phase-aligned in a system—such as ADSL—that transmits 4000 symbols/second:

Number of carriers	**Frequency of perfect alignment for random data**	**Frequency of alignment for Shively's bit-spreading**
4	500 times per second	4000 times per second
8	31 times per second	2000 times per second
16	Once every 8 seconds	500 times per second
24	Once every 35 minutes	125 times per second
32	Once every 6 days	31 times per second
48	Once every 1100 years	2 times per second
52	One every 17,850 years	Once per second

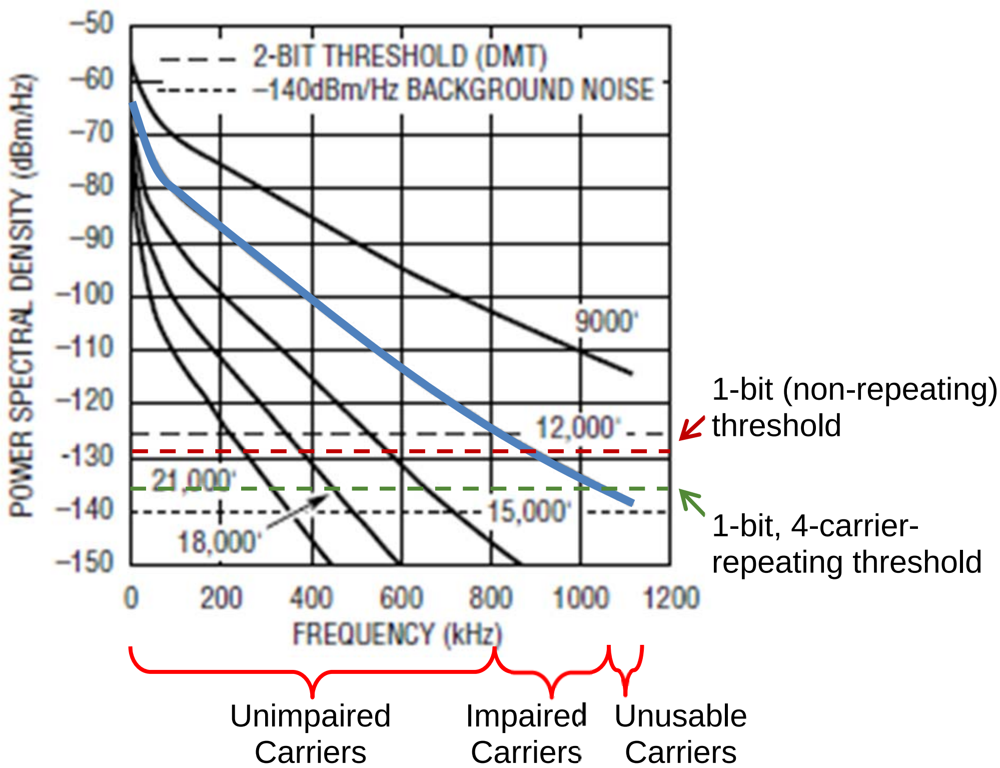
CSCO-1026, ¶28.

Dr. Short used an example of Shively's technique on 16 carriers. *See* TQ-2003, ¶66. The table above shows that his assumption that the carriers would have a Gaussian probability distribution grossly underestimates the likelihood of phase alignment—by several orders of magnitude—and thus grossly underestimates the probability of clipping. CSCO-1026, ¶29. Dr. Short effectively assumed that all 16 carriers would be phase-aligned only once every 8 seconds. In reality Shively's technique will cause them to be phase-aligned *500 times per second*. *Id.* Because Dr. Short's numerical analysis is based entirely on an erroneous assumption, his results are unreliable. *Id*. Thus, Dr. Short's opinions and his analysis regarding Shively's PAR should not be accorded any weight.

C. A rigorous analysis of using Shively's technique shows that it significantly increases PAR and the likelihood of clipping

Because Shively's technique causes multiple subcarriers to be purposely set to the same phase, a system employing Shively's technique cannot be analyzed using a Gaussian approximation. While a POSITA would have intuitively known that Shively's technique would significantly increase PAR, quantifying the exact level of increase would have called for running a numerical simulation of the transmitter. CSCO-1026, ¶42. Such simulations were commonly created and performed by engineers working on ADSL designs in the 1990s. CSCO-1026, ¶43; *see, e.g.*, CSCO-1030, p.367; CSCO-1032, p.774; CSCO-1033, p.758; CSCO-31, ¶¶5-6.

Consistent with what a POSITA would have done to quantify the effect of Shively's technique on PAR, Dr. Tellado created a simulation based, in part, on TQ Delta's Exhibit 2009, Figure 6, shown below:



CSCO-2009, Fig. 6 (annotated).

To show the effect of Shively's technique on PAR, Dr. Tellado analyzed the attenuation graph of a 12,000 foot AWG 26 cable. Dr. Tellado's analysis shows that the 12,000 foot cable would have approximately 188 unimpaired (with 6 left unused), 53 impaired, and 15 unusable carriers. CSCO-1026, ¶¶37-38. Because Shively suggests grouping impaired carriers into groups of four, Dr. Tellado arranged 52 of the 53 carriers into 13 groups of 4 carriers each. CSCO-1026, ¶38.

Dr. Tellado simulation uses the above analysis and includes four scenarios:

- Scenario #1: An all-carriers baseline simulates an ADSL transmitter employing QAM-4 modulation of random data on all 250 downstream

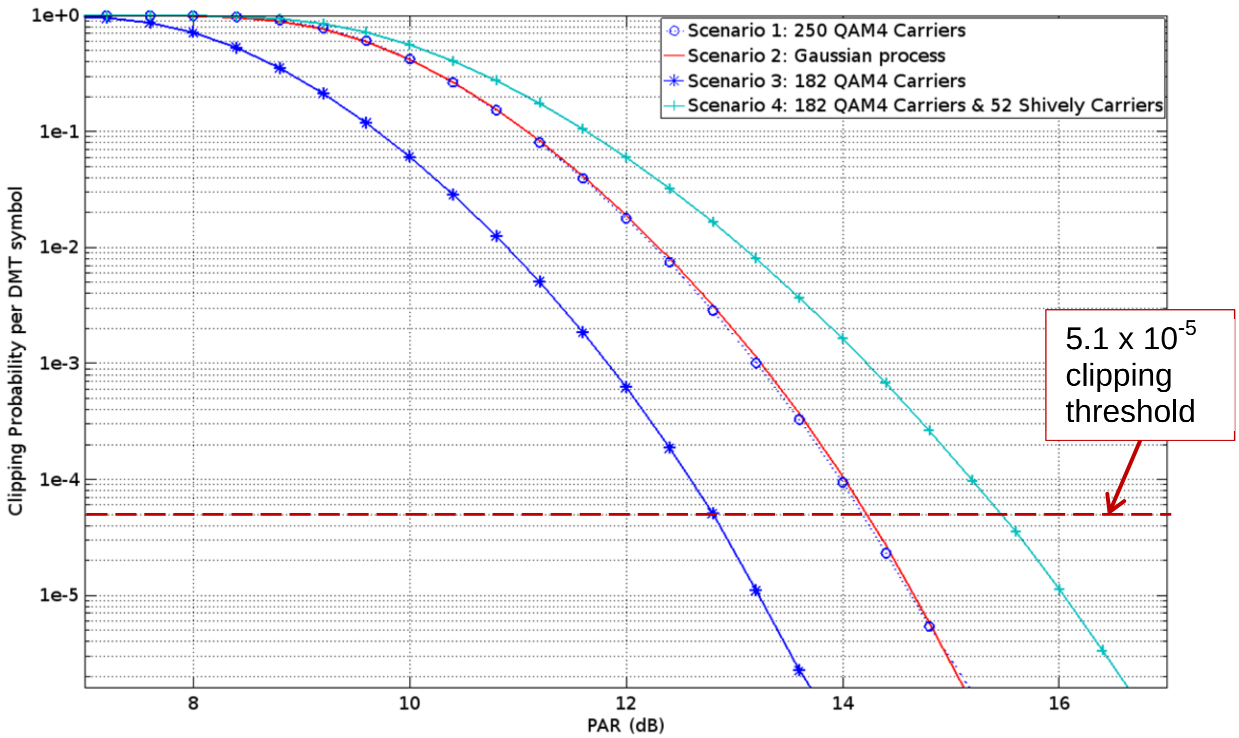
carriers. The transmitter is operating on full average power. CSCO-1026, ¶47.

- Scenario #2: A Gaussian distribution with the same power as the all-carriers baseline shows that Gaussian approximation can closely estimate the power required to transmit data on all 250 carriers. CSCO-1026, ¶47.
- Scenario #3: A 12,000 foot baseline simulates an ADSL transmitter employing a QAM-4 modulation of random data on 182 out of 250 downstream carriers. Because only 182 carriers are modulated with random data, the transmitter operates on approximately 79% of full average power. CSCO-1026, ¶47.
- Scenario #4: A Shively 12,000 foot scenario simulates an ADSL transmitter employing QAM-4 modulation of random data on the 182 carriers, and using Shively's technique to transmit additional 13 bits of data spread across 52 impaired carriers (in 13 groups of 4 each). CSCO-1026, ¶47.

The graph below shows the results of the four scenarios.[4] The ANSI T1.413-1995 standard's maximum clipping rate, when expressed in terms of DMT symbol

[4] Such graphs were commonly used in the prior art to evaluate transmitter designs. CSCO-1026, ¶46; CSCO-1030, p.367; CSCO-1024, p.4.

clipping as graphed, corresponds to a DMT symbol clipping rate of approximately 5.1×10^{-5}. CSCO-1026, ¶48.



CSCO-1026, ¶¶48-49.

The impact of Shively's technique is evident in comparing Scenario #3 to Scenario #4. If only 182 carriers carry data (Scenario #3), the PAR at the clipping threshold is approximately 12.9 dB. But when Shively's technique (Scenario #4) is applied to the 52 impaired carriers (13 groups of four), the PAR increases to approximately 15.5 dB. This increase in PAR is significant, and a POSITA in the 1990s would have considered a PAR increase of 2.6 dB—representing an 82% increase in power—to be very large. CSCO-1026, ¶49.

The increase in PAR can also be appreciated by considering response of an

ordinary ADSL transmitter (represented by Scenario #1 that intersects the clipping threshold at a PAR of 14.2 dB) when presented with a DMT symbol employing Shively's technique. A transmitter handling only PAR of 14.2, used in Scenario #4, would have a clipping rate of 10^{-3} and incur a clipping event approximately 4 times per second. CSCO-1026, ¶50. Thus, the ordinary ADSL transmitter would not meet the clipping requirement of ANSI T1.413-1995 when presented with a DMT symbol employing Shively's technique under the conditions of Scenario #4. CSCO-1026, ¶50.

Dr. Tellado's simulation considers only specific scenarios. Shively's technique would have an even worse impact on PAR in other scenarios that take into account additional factors, such as other line lengths and crosstalk noise. CSCO-1026, ¶51.

Thus, the correct analysis of Shively's technique confirms what a POSITA would have recognized without performing any calculations: that Shively's technique significantly increases PAR. CSCO-1026, ¶52. Because (as the parties agree) an increase in PAR is undesirable in multicarrier systems, a POSITA would have sought out to pair Shively's technique with techniques for reducing PAR, such as phase scrambling taught by Stopler. CSCO-1026, ¶54.

D. High PAR causes more problems than just clipping

TQ Delta argues that because Shively does not present "a PAR problem",

there is no need to look for a solution to reduce PAR. Resp., p.50. This argument is based on TQ Delta's erroneous 18,000-foot analysis (which is invalid, as discussed above) and its attempt to limit a "PAR problem" to situations in which a "PAR-induced error[]" such as signal clipping occurs. Resp., pp.7-8. But a high PAR was known to cause multiple kinds of problems, not just clipping. Dr. Short admitted that equipment designed to handle a high PAR signal could be larger, more expensive, more power hungry, and less efficient. TQ-2003, ¶26; CSCO-1027, 45:21-46:19. He further admitted that these problems would motivate engineers to look for ways to reduce PAR. CSCO-1027, 46:23-47:2. Prior art articles confirm that engineers sought to minimize the equipment cost, power consumption, and heat generation associated with ADSL's high-PAR signals. *See* CSCO-1029, pp.70 & 176-177; CSCO-1030, p.362.

In summary, the negative implications of a high-PAR signal are not limited to signal clipping. The numerous problems associated with high PAR would have motivated a POSITA to look for ways to reduce the PAR of Shively's technique. CSCO-1026, ¶¶3, 54.

E. Stopler's diagonalization technique is optional, not required

TQ Delta argues that Shively and Stopler cannot be combined because Stopler's "diagonalization" technique would introduce unacceptable latency. Resp., pp.51-55. TQ Delta's argument is meritless.

First, the obviousness combination does not rely on Stopler's diagonalization technique. Rather, the combination incorporates Stopler's phase scrambling technique into Shively in order to offset the PAR increase caused by Shively's technique. *See* Pet., p.14. Because the combination does not rely on diagonalization, TQ Delta's argument is simply a red herring.

Second, even within Stopler, the use of diagonalization is optional. Stopler makes statements like "regardless of whether diagonalization is being used." CSCO-1012, 10:17; *see also id.*, 13:1-3. Because Stopler's diagonalization technique is optional, any incompatibility between diagonalization and Shively is irrelevant. CSCO-1026, ¶60.

Finally, TQ Delta's assertion that the slope of Stopler's diagonalization technique causes unacceptable latency is simply incorrect. Stopler expressly contemplates that "[o]ther slopes may be used" and advises "taking into account trade-offs between latency and noise immunity." CSCO-1012, 8:35, 12:47-48. Thus, Stopler's diagonalization technique could use a slope that would not cause unacceptable latency. CSCO-1026, ¶61.

VI. Conclusion

None of the TQ Delta's arguments withstand scrutiny. For the reasons stated above and in Cisco's Petition, the Board should find the challenged claims unpatentable.

Respectfully submitted,

Date: June 9, 2017

/David L. McCombs
David L. McCombs
Registration No. 32,271
Attorney Docket No.: 43614.275

VII. Certificate of Word Count

Pursuant to 37 C.F.R. § 42.24, the undersigned attorney for the Petitioner, Cisco Systems, Inc. ("Cisco"), declares that the argument section of this Petition (Sections I-VI) has a total of 5488 words, according to the word count tool in Microsoft Word™.

/David L. McCombs/
David L. McCombs
Registration No. 32,271

CERTIFICATE OF SERVICE

The undersigned certifies service under 37 C.F.R. §§ 42.6(e) by electronic mail a true and correct copy of *PETITIONER'S REPLY AND EXHIBITS 1021-1034* on June 8, 2017, upon counsel for the Patent Owner via the listed email below:

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Dated: June 8, 2017

Respectfully submitted,

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Paper 21
Entered: June 22, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Cases IPR2016-01006 (Patent 7,835,430 B2)[1]
IPR2016-01008 (Patent 8,238,412 B2)
IPR2016-01020 (Patent 9,014,243 B2)
IPR2016-01021 (Patent 8,718,158 B2)

[1] DISH Network, L.L.C., Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc. have been joined in these proceedings. *See,* IPR2017-00251, IPR2017-00253, IPR2017-00254, IPR2017-00255, IPR2017-00417, IPR2017-00418, IPR2017-00419, and IPR2017-00420. This Order addresses the same issues in the above listed proceedings. Therefore, we issue one Order to be filed in all of the above listed proceedings. The parties, however, are not authorized to use this style of filing in subsequent papers.

Before SALLY C. MEDLEY, KALYAN K. DESHPANDE, and TREVOR M. JEFFERSON, *Administrative Patent Judges*.

MEDLEY, *Administrative Patent Judge*.

ORDER
Conduct of the Proceeding
37 C.F.R. § 42.5

On June 21, 2017, a conference call was held involving counsel for the respective parties and Judges Medley, Deshpande, and Jefferson. The purpose of the conference call was for Patent Owner to seek authorization to file a motion to strike Petitioner's Reply and/or to file a sur-reply to Petitioner's Reply in each of the above listed proceedings. Patent Owner opposed.

During the conference call, we explained that Patent Owner is not authorized to file motions to strike or sur-replies. We did authorize, however, Patent Owner to file a paper, limited to two pages, which provides an itemized listing, by page and line number, of what statements and evidence in the Petitioner's Reply are deemed by Patent Owner to be beyond the proper scope of a reply. No argument is to be included in the contents of the submission. We also authorized Petitioner to file a responsive paper, limited to two pages, which provides an item-by-item response to the items listed in Patent Owner's submission. Each item in Petitioner's responsive paper would identify that part of Patent Owner's Response, by page and line number, to which the corresponding item complained of by the Patent Owner is provided as a response, if indeed that is the case. No argument is to be listed in the contents of the submission.

IPR2016-01008 (Patent 8,238,412 B2)
IPR2016-01020 (Patent 9,014,243 B2)
IPR2016-0102 (Patent 8,718,158 B2)

Accordingly, it is

ORDERED that Patent Owner's submission in each of the above listed proceedings is due on June 27, 2017; and

FURTHER ORDERED that Petitioner's submission in each of the above listed proceedings is due on July 3, 2017; and

FURTHER ORDERED that the party responsible for obtaining the court reporter shall file a copy of the transcript of the conference call as an exhibit by June 27, 2017.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01021[1]
Patent 8,718,158 B2

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[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020[1]
Patent No. 9,014,243

PATENT OWNER'S LISTING OF IMPROPER REPLY / NEW ARGUMENT AND EVIDENCE

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

Pursuant to the Board's Order (Paper No. 21) entered June 22, 2017, Patent Owner provides the following listing of statements and evidence in that are beyond the proper scope of a reply, including new argument and evidence:

(1) Petitioner's Reply at p. 8, lns. 16-17 ("scrambling the …"), and 19-21 (In light …");

(2) Petitioner's Reply at p. 9, lns. 1-3 ("Rather than …"), and 6-8 ("There is …");

(3) Petitioner's Reply at p. 11, lns. 9-11 ("Elsewhere TQ Delta …");

(4) Petitioner's Reply at p. 12, ln. 6 – p. 13, ln. 20 ("D. Phase scrambling …");

(5) Petitioner's Reply at p. 14, lns. 9-16 ("First, the …");

(6) Petitioner's Reply at p. 15, ln. 6 ("But the …") – p. 16, ln. 3;

(7) Petitioner's Reply at p. 17, lns. 8-11 ("Furthermore, there …");

(8) Petitioner's Reply at p. 18, ln. 14 ("The illogic …") – p. 19, ln. 2;

(9) Petitioner's Reply at p. 22, ln. 17 ("Notably, the …") – p. 26, ln. 7;

(10) Petitioner's Reply at p. 27, ln. 16 ("1. Likelihood of …") – p. 36, ln. 18;

(11) Petitioner's Reply at p. 36, ln. 19 ("D. High PAR …") – p. 37, ln. 16;

(12) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 3, ln. 21 ("However, Shively …") – p. 9, ln. 2;

(13) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 10, ln. 11 ("The likelihood …") – p. 17, ln. 10;

(14) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 20, ln. 11 ("Below I …") – p. 25, ln. 13;

(15) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 25, ln. 20 ("A POSITA …") – p. 32, ln. 9;

(16) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 32, ln. 16 ("Shively's bit-spreading …") – p. 33, ln. 12;

(17) Ex. CSCO-1026 (Tellado Reply Decl.) at p. 33, ln. 17 ("First, I …") – p. 35, ln. 4;

(18) Ex. CSCO-1018 at p.s 138, 140, 142, and 144;

(19) Ex. CSCO-1022 (entirety);

(20) Ex. CSCO-1023 (entirety);

(21) Ex. CSCO-1024 (entirety);

(22) Ex. CSCO-1025 (entirety);

(23) Ex. CSCO-1028 (entirety);

(24) Ex. CSCO-1029 (entirety);

(25) Ex. CSCO-1030 (entirety);

(26) Ex. CSCO-1032 (entirety);

(27) Ex. CSCO-1033 (entirety);

(28) Ex. CSCO-1034 (entirety); and

(29) Ex. 2013 (Tellado Redirect Dep. Tr.) at p. 145, ln. 1 – p. 153, ln. 12.

Dated: June 27, 2017

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CERTIFICATE OF SERVICE

I hereby certify that the Patent Owner's Listing of Improper Reply/New Argument and Evidence in connection with *Inter Partes* Review Case IPR2016-01020 was served on this 27th day of June, 2017 by electronic mail to the following:

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
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COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020[1]
Patent No. 9,014,243

PATENT OWNER'S MOTION TO EXCLUDE EXHIBITS 1022, 1023, 1024, 1025, and 1028, PORTIONS OF THE TELLADO TESTIMONY (EX. 2013), AND PORTIONS OF THE 2nd TELLADO DECLARATION (EX. 1026) PURSUANT TO 37 C.F.R. § 42.64(c)

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

I. INTRODUCTION

Patent Owner TQ Delta, LLC submits the following motion to exclude. The exhibits in question should be excluded for Petitioner's failure to cite documents that constitute prior art, its untimely introduction of exhibits on Reply that are irrelevant to the substantive issues and not cited in the Reply, rendering them irrelevant, and its expert's failure to retain copies of testing he performed on which he relies.

II. EXHIBITS 1022, 1023, 1024, 1025, AND 1028, PORTIONS OF THE TELLADO TESTIMONY (EX. 2013) AND PORTIONS OF THE SECOND TELLADO DECLARATION (EX. 1026) SHOULD BE EXCLUDED

A. EXHIBIT 1022 SHOULD BE EXCLUDED UNDER AT LEAST FED. R. EVID. 402

Exhibit 1022 is a chapter and some additional pages from a book titled *WiMedia UWB.* Patent Owner timely objected to Exhibit 1025. *See* Paper 22 at 1.

Exhibit 1022 was not included with the Petition and it is not cited or explained in the Reply. It is also not cited in the Second Tellado Declaration (submitted with the Petitioner Reply). Exhibit 1022 should be excluded for this reason alone as irrelevant and untimely under Fed. R. Evid. 402, Fed. R. Evid. 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

Moreover, Exhibit 1022 should be excluded as irrelevant because it is not prior art and therefore irrelevant to the knowledge of one of ordinary skill in the art as of 1999. Both the book itself and the chapter in question (Ch. 3) bear copyright dates of 2008. *See* Ex. 1022 at 3, 11. Patent Owner timely objected to Exhibit 1025. *See* Paper 22 at 2. There is no evidence that the book or the chapter cited were publicly-available or otherwise constituted prior art as of 1999, the filing date of the ’243 patent. *See* Ex. 1001 at cover. In other words, Exhibit 1022 is nine years too late. Exhibit 1022 is irrelevant to show or evidence the knowledge of one of ordinary skill as of the date the invention was made.

The relevant time-frame for patentability is the time of the invention, and no later than the effective filing date. *See Synthon IP, Inc. v. Pfizer, Inc.*, C.A. No. 1:05cv1267, 2007 U.S. Dist. LEXIS 26115, at *15-17 (E.D. Va. Apr. 6, 2007) (“[T]he obviousness inquiry asks whether the subject matter ‘would have been obvious [to one of ordinary skill in the art] *at the time the invention was made*.’”), quoting *Alza Corp. v. Mylan Labs., Inc.*, 464 F.3d 1286, 1289 (Fed. Cir. 2006) (emphasis added in *Synthon*); *Walt Disney Prods. v. Fred A. Niles Communs. Ctr., Inc.*, 369 F.2d 230, 234 (7th Cir. 1966) (“The difference between the subject matter sought to be patented and the prior art must be such that the subject matter as a whole would have been obvious to a person having ordinary skill in the art to

which said subject matter pertains, as of the date of the invention."; explaining that the use of knowledge from a later date constituted impermissible hindsight).

Because Exhibit 1022 was nine years too late, it is irrelevant under Fed. R. Evid. 402, and should be excluded.[2]

B. EXHIBIT 1025 SHOULD BE EXCLUDED AS IRRELEVANT UNDER AT LEAST FED. R. EVID. 402

Exhibit 1025 is a thesis from Petitioner's Expert. It should be excluded for multiple reasons. Patent Owner timely objected to Exhibit 1025. *See* Paper 22 at 2.

Petitioner submitted Exhibit 1025 (Tellado thesis) for the first time on Reply. Like Exhibit 1022, the thesis was not cited in either the Petition or the Reply. Exhibit 1025 should be excluded for this reason alone as irrelevant and untimely under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

Moreover, Exhibit 1025 should be excluded as irrelevant because it is not prior art and therefore irrelevant to the knowledge of one of ordinary skill in the art as of 1999. The only expert testimony offered by Petitioner in this case is offered to show the viewpoint of a person of ordinary skill in the art as of the filing date of

[2] Exhibit 1022 should also be excluded because it is not cited in either the Reply or the Second Tellado Declaration.

November 9, 1999. *See* Ex. 1009 ¶ 7. But, like Exhibit 1022, there is no evidence that the Tellado thesis was publicly accessible as of this filing date. The Tellado thesis itself lists two dates, without explanation—(1) a copyright date of 2000 (Ex. 1025 at 2); and (2) the statement "September 1999" under the author's name. *Id.* at 1. After Patent Owner's objection to Ex. 1025, Petitioner submitted supplemental evidence to allege only that the thesis was "catalogued by the Stanford University Libraries on May 9, 2000 (field 916) and was publicly available from the Stanford University Libraries since this date." Ex. 1035 ¶ 2, at 2.

The proponent of the publication, here Petitioner, bears the burden of producing sufficient proof of dissemination or sufficient proof that the publication was otherwise available and accessible. *See SRI Int'l, Inc. v. Internet Sec. Sys., Inc.*, 511 F.3d 1186, 1194 (Fed. Cir. 2008); *see also Carella v. Starlight Archery & Pro Line Co.*, 804 F.2d 135, 139 (Fed. Cir. 1986) ("[O]ne who wishes to characterize the information, in whatever form it may be, as a 'printed publication' should produce sufficient <u>proof of its dissemination</u> or that it has otherwise been available and accessible to persons concerned with the art to which the document relates . . . .").

To be relevant, a publication must have been publicly accessible as of the effective filing date. In this case, Petitioner has admitted that the relevant date, and indeed the only date on which its expert offers his opinions regarding the

knowledge of a person of ordinary skill is November 9, 1999. *See* Ex. 1009 ¶ 7. The supplemental evidence submitted by Petitioner shows, at best, a date of public accessibility ("catalog[ing]") of May 9, 2000, which falls **after** date of knowledge of a person of ordinary skill (November 9, 1999) proffered by Petitioner's expert (*see* Ex. 1009 ¶ 7). That date, not surprisingly, matches the earliest claimed filing date for the '243 patent. *See* Ex. 1001 at cover; Ex. 1008. Therefore, the Tellado thesis (Ex. 1025) is too late in time and is irrelevant to the testimony of Tellado, and irrelevant to this review under Fed. R. Evid. 402.

C. ALL OR PORTIONS OF PARAGRAPHS 16, 29, 42 (INCLUDING HEADER), 43, AND 52 OF THE SECOND TELLADO DECLARATION (EX. 1026) AND PAGES 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, AND 61:19-23 OF THE TELLADO TRANSCRIPT (EX. 2013) SHOULD BE EXCLUDED

During cross-examination, Petitioners' expert (Dr. Tellado) testified that he relied on at least two "MatLab" computer simulations to support his opinions, but materials relating to only one simulation were provided to Patent Owner. The materials related to the second simulation were apparently written over, discarded, and/or withheld from Patent Owner. *See* Ex. 2013 at 47:9-48:6, 57:6-17, 58:10-14, 59:6-12, 60:3-8, 60:9-20. Patent Owner timely objected to the failure to disclose or retain evidence and the possible discarding of evidence. *See* 6/22/17 A. Karp e-

mail to counsel; 6/22/17 A. Karp e-mail to Board; Ex. 2013 at 57:25-58:2, 62:13-63:4.

In addition to the testing of the 12,000 foot loop that Dr. Tellado performed and disclosed in connection with his second declaration, Dr. Tellado also performed an undisclosed simulation using a MatLab script for an "AWG26 loop of 18,000 feet." Ex. 2013 at 46:10-18. But, Dr. Tellado testified on cross-examination that the MatLab script and simulation results for an 18,000 foot loop formed the basis of his opinion that Dr. Short's (Patent Owner's expert) Gaussian approximation was "poor." *See, e.g.*, Ex. 2013 at 46:19-47:8, 51:5-20, 52:25-53:12. When asked about whether he has or had an electronic or hard copy of the MatLab script or simulation results, whether he communicated the same to anyone else, or whether he discarded or deleted the same, Dr. Tellado could only say that did not recall. *See, e.g.*, *id.* at 47:9-48:6, 57:6-17, 58:10-14, 59:6-12, 60:3-8, 60:9-20.

Without providing Patent Owner with access to the MatLab simulation result, Dr. Tellado has not disclosed the facts and data underlying his opinion, in violation of 37 C.F.R. § 42.65(b). Under Rule 65(b), when Petitioner's expert relied on a technical test or data from it, he was required to "provide an affidavit explaining" the test and its underlying data. *See* 37 C.F.R. § 42.65(b) (setting forth the requirements of the affidavit); *3D-Matrix, Ltd., v. Menicon Co., Ltd.*, IPR2014-

00398, Paper 11, August 1, 2014. Moreover, it remains impossible to cross-examine Dr. Tellado regarding his opinions regarding simulations and his criticisms of Dr. Short, as reflected in at least (1) Exhibit 1026, Second Tellado Declaration, ¶ 16 (last 2 sentences), ¶ 29, ¶ 42 (including preceding header), ¶ 43 (first sentence), ¶ 52, and (2) Exhibit 2013, Tellado transcript at 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23. *See Altaire Pharma., Inc. v. Paragon Biotek, Inc.*, PGR2015-00011, Paper 122, November 14, 2016 ("Without the necessary information prescribed in § 42.65(b), we cannot determine whether the evidence Petitioner relies on is credible.").

Moreover, the unavailable MatLab simulation information was required to be disclosed as routine discovery at least because (1) it was relied on or cited by Dr. Tellado during his testimony under 37 C.F.R. §§ 41.51(b)(1)(i); *see Lumentum Holdings, Inc. v. Capella Photonics, Inc.*, IPR2015-00731, Paper 32, February 5, 2016 (information relied on was required to be disclosed regardless of whether it was actually called an exhibit in a paper); *MaxLinear, Inc., v. Cresta Tech. Corp.*, IPR2015-00594, Paper 35, January 27, 2016 (testimony referencing an exhibit, although not formally; and (2) it is inconsistent, at least, with Petitioners' (and Petitioners' expert's) positions regarding the accuracy of Dr. Short's analysis. 37 C.F.R. §§ 42.51(b)(1)(i), (b)(1)(iii); *see also MaxLinear*, IPR2015-00594, Paper 35. Therefore, this information should already have been produced.

As a result of the improper withholding, the following paragraphs of the Second Tellado Declaration (Ex. 1026) should be excluded under Fed. R. Evid. 702 as being based on insufficient facts or data: ¶ 16 (last 2 sentences), ¶ 29, ¶ 42 (including preceding header), ¶ 43 (first sentence), and ¶ 52. For the same reasons, the following pages of the Tellado transcript (Ex. 2013) should be excluded under Fed. R. Evid. 702: 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23.

As a result of Dr. Tellado's refusal to disclose the underlying facts and data on cross-examination, the same portions of the Second Tellado Declaration (Ex. 1026) and the Tellado transcript (Ex. 2013) should also be excluded under Fed. R. Evid. 705.

For at least these reasons, and due to Dr. Tellado's withholding of the simulation data, the above-referenced portions of the Second Tellado Declaration (Ex. 1026) and Tellado transcript (Ex. 2013) should be excluded under Fed. R. Evid. 702, 705, 37 C.F.R. §§ 41.51(b)(1)(i) & 41.51(b)(1)(iii), and 37 C.F.R. § 42.65(b).

D. EXHIBITS 1023, 1024, AND 1028, AND PORTIONS OF DR. TELLADO'S REDIRECT ADDRESSING THE SAME (EX. 2013) SHOULD BE EXCLUDED UNDER F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, AND/OR 37 C.F.R. § 42.61

Exhibits 1023, 1024, and 1028, each of which was cited in the Reply for the first time, should be excluded under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23,

and/or 37 C.F.R. § 42.61. Patent Owner timely objected to these exhibits. *See* Paper 22 at 1-2. Similarly, the portions of Dr. Tellado's redirect regarding the same (Ex. 2013 at 146:20-149:7 (Ex. 1023), 149:8-152:25 (Ex. 1024)) should also be excluded under F.R.E. 402, F.R.E 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61. Patent Owner also timely objected to this redirect testimony. *See* Ex. 2013 at 146:20-149:7, 149:8-152:25

These exhibits purportedly attempt to fill in a major shortcoming in the evidentiary record—namely, there is no evidence in the Petition (besides an unsupported, conclusory allegation by Petitioners' expert) that a person having ordinary skill in the art would have recognized that randomizing the phases of subcarriers in a multicarrier signal would result in a lower peak-to-average power ratio ("PAR") in Shively's system. Both the Petition and Petitioners' expert's first declaration baselessly state: "A POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same [one or more] bits, but without those two subcarriers having the same phase." Petition at p. 14; Ex. 1009 (Dr. Tellado's First Declaration) at ¶ 67. No supporting evidence was provided.

Now, when Patent Owner has no chance to respond, Petitioners seek to remedy this deficiency in the Petition (and first expert declaration) through attorney argument regarding these exhibits. Exhibit 1023, Petitioners allege,

discloses "random phasor transformation" (Paper 17 at 13)—although they never explain how such a "phasor" transformation equates to randomizing phases on each subcarrier to reduce PAR. With respect to Exhibit 1024, Petitioners purport that it discloses "phase rotated signal parts," Paper 17 at 13, again with no further explanation as to how this shows phase scrambling. And regarding Exhibit 1028, Petitioners merely claim it demonstrates having a "phase rotation applied to each [DMT] tone." Paper 17 at 13. Again, no explanation is provided as to how this equates to phase scrambling to lower PAR.

Thus, Exhibits 1023, 1024, and 1028 are too late and not relevant to the timely opinions and art actually raised in this review, and thus inadmissible under F.R.E. 402, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61. Petitioners should not be allowed to supplant the record by filling in the gaps left by their Petition and supporting declaration. Moreover, because Patent Owner has no opportunity to respond to the new exhibits at this late stage, the danger of unfair prejudice substantially outweighs any minimal probative value they may have, rendering them inadmissible under Fed. R. 403.

Recognizing the shortcoming in its citations, Petitioner took up these topics on deposition redirect of its own expert also, in an untimely attempt to fill in the gaps. *See* Ex. 2013 at 146:20-149:7 (Ex. 1023), 149:8-152:25 (Ex. 1024). Having failed to address these exhibits in its Petition, first Tellado Declaration, and Second

Tellado Declaration, these exhibits are too late and not relevant to the timely opinions and art actually raised in this review, and thus inadmissible for the same reasons under Fed. R. Evid. 402, 403, 37 C.F.R. § 42.23, and/or 37 C.F.R. § 42.61.

III. CONCLUSION

For all the foregoing reasons, TQ Delta respectfully requests that the Board exclude Exhibits:

- Exhibit 1022, *WiMedia UWB* (including Chapter 3);
- Exhibit 1025, the Tellado thesis;
- Exhibit 1026, the Second Tellado Declaration, ¶ 16 (last 2 sentences), ¶ 29, ¶ 42, ¶ 43 (first sentence), ¶ 52;
- Exhibit 2013, the Tellado Transcript, at 46:19-47:16, 49:1-50:13, 51:5-56:23, 57:6-12, and 61:19-23;
- Exhibit 1023, 1024, and 1028, newly-cited art; and
- Exhibit 2013, The Tellado Transcript, at 146:20-149:7 and 149:8-152:25.

Dated: June 30, 2017

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CERTIFICATE OF SERVICE

I hereby certify that the Patent Owner Motion to Exclude in connection with *Inter Partes* Review Case IPR2016-01020 was served on this 30th day of June, 2017 by electronic mail to the following:

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,
v.
TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020 (Patent No. 9,014,243)[1]
Case No. IPR2016-01021 (Patent No. 8,718,158)[2]

PATENT OWNER'S MOTION FOR DISCOVERY FILED UNDER 37 C.F.R. § 42.51(b)

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[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

[2] DISH Network, L.L.C., who filed a Petition in IPR2017-00255, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00417, have been joined in this proceeding.

Ex. 2013, 25:13-23 & 27:9-19. Dr. Tellado's testimony is relevant to Petitioner's argument that "Shively is not limited to cable lengths of 18,000 feet." Petitioner's Reply, Paper 17, p. 22.

Response to Observation # 2:

TQ Delta mischaracterizes Dr. Tellado's testimony because the cited statements from Dr. Tellado do not discuss the noise characteristics used by Dr. Short. *See* Ex. 2013, 46:1-5. Dr. Tellado did not agree that Dr. Short's analysis was based on a loop with high noise. Dr. Tellado's declaration provided annotated graphs showing that ADSL systems could have noise levels much higher than "-140 dBm/Hz, which was the 'background noise' level shown in the attenuation graph relied upon by Dr. Short." Ex. 1026, ¶ 9; *see also id.*, ¶¶ 10-13.

Response to Observation # 3:

TQ Delta's observation is misleading because Dr. Tellado did not rely on the 18,000-foot "quick estimate" to state in paragraph 29 of his declaration (Ex. 1026) that "Dr. Short's analysis is flawed…." PO's Motion for Observation, p. 4. Rather, to show that Dr. Short's use of a Gaussian approximation was flawed, Dr. Tellado relied on the simple math and logic explained in paragraphs 15-28 of his declaration (Ex. 1026). TQ Delta also ignores Dr. Tellado's testimony explaining with "Graph 2" of Ex. 1026 (p. 30) that a system using Shively's technique cannot be modeled accurately with a Gaussian approximation:

> Q. Well, would it be to the left of the Scenario 1 line that you show here in graph 2?
>
> A. … So when you have a Gaussian process, it drops like the red line; if you have a non-Gaussian process, it could have a different slope. And it could look better at very high clipping rates, but it could be worse at low clipping rates. So I don't remember exactly where it crossed. It didn't have the same slope as a Gaussian process. That's why I said the Gaussian approximation was not a good approximation.

Ex. 2013, 55:8-56:2.

Response to Observation # 5:

TQ Delta's observation is misleading because Dr. Tellado did not rely on the 18,000-foot "quick estimate" to state in paragraph 29 of his declaration (Ex. 1026) that "Dr. Short's analysis is flawed … ." PO's Motion for Observation, p. 7. Rather, to show that Dr. Short's use of a Gaussian approximation was flawed, Dr. Tellado relied on the simple math and logic explained in in paragraphs 15-28 of his declaration (Ex. 1026). TQ Delta also ignores Dr. Tellado's testimony explaining with "Graph 2" of Ex. 1026 (p. 30) that a system using Shively's technique cannot be modeled accurately with a Gaussian approximation:

> A. Can you see graph 2? You see the solid red line?
>
> Q. Yes.

> A. That is the Gaussian process. You see Scenario 1 with 250 QAM-4 carriers? Doesn't it look very similar to the Gaussian process, the round, blue circles?
>
> Q. Yes.
>
> A. So I call this following a Gaussian process. What about the cyan Scenario 4 curve? Does it -- is it tight with the Gaussian process Scenario 2 curve? It's diverging. It's worse than. The Gaussian process has a lower PAR than Scenario 4. It's not a good model. This shows you a Scenario 4 that has Shively carriers cannot be modeled accurately with a Gaussian process in Scenario 2.

Ex. 2013, 49:13-50:5.

Response to Observation # 6:

TQ Delta mischaracterizes Dr. Tellado's testimony by omitting Dr. Tellado's explanation for why a non-Gaussian process (such as in Shively) cannot be intuitively compared to a Gaussian process:

> A. … So when you have a Gaussian process, it drops like the red line; if you have a non-Gaussian process, it could have a different slope. And it could look better at very high clipping rates, but it could be worse at low clipping rates. So I don't remember exactly where it crossed. It didn't have the same slope as a Gaussian process. That's why I said the Gaussian approximation was not a good approximation.

Ex. 2013, 55:19-56:2.

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., et al.
Petitioner,

v.

TQ DELTA LLC,
Patent Owner.

Case IPR2016-01020 (Patent 9,014,243)
Case IPR2016-01021 (Patent 8,718,158)

Record of Oral Hearing
Held: August 3, 2017

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*

APPEARANCES:

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The above-entitled matter came on for hearing on Thursday, August 3, 2017, commencing at 2:56 p.m., at the U.S. Patent and Trademark Office, 600 Dulany Street, Alexandria, Virginia.

P R O C E E D I N G S

JUDGE MEDLEY: Good afternoon. We are on the record. This is the hearing for IPR 2016 01020 and 1021. Cisco Systems, et al. versus TQ Delta. Each side has 40 minutes to argue.

Petitioner, you will proceed first, to present your case with respect to the challenged claims and grounds for which we instituted a trial. And then thereafter, patent owner, you may have time to respond and petitioner, you may reserve rebuttal time.

At this time we would like the parties to please introduce themselves beginning with petitioner.

MR. MCCOMBS: Your Honors, I'm David McCombs with Haynes & Boone, and with me is Theo Foster and Gregory Huh and Dina Blikshteyn. Also we have with us today, on behalf of Dish Networks we Jennifer Volk and Stephen McBride from Cooley. And then also we have for the Comcast entities we have Corey Manley with Duane Morris.

JUDGE MEDLEY: And Mr. Foster, you will be presenting?

MR. FOSTER: That's correct.

JUDGE MEDLEY: And patent owner?

MR. MCANDREWS: Good afternoon, Your

Honor. I'm Peter McAndrews with McAndrews Held & Malloy. With me I have Rajendra Chiplunkar, Chris Scharff, and Ben Mann from our law firm. I also have from TQ Delta, their representative is Mark Roach and Nada Roget, and one of the inventors from the patent portfolio, Marcos Tzannes.

JUDGE MEDLEY: All right. On August 1st, 2017, patent owner filed papers styled Patent Owner's Objections to Petitioner's Demonstratives. Patent owner's objections are dismissed because they are improper since patent owner did not demonstrate sufficiently that the contents of the objected-to slides raised new issues or evidence, rather the objected-to slides contained references to arguments and evidence of record.

Again, we remind the parties that the demonstratives are not evidence but demonstratives and that we may not even enter them into the record. For all these reasons, we dismiss the objections to petitioners' demonstratives.

Petitioner, at this time you may proceed.

MR. FOSTER: Thank you, Your Honor.

Good afternoon and may it please the court. I'd like to jump straight into the issues in this case and first point out that patent owner

does not dispute that the substantive limitations of the claims at issue here are taught in the prior art. The main issue raised in papers concerns the obviousness of combining the two main references. Those are Shively and Stopler. And we believe that that combination, looking at Slide 2, that combination flows from ordinary engineering problem solving skills applied in light of three simple observations that would have been apparent to a person of ordinary skill in this art.

Those are, first, that Shively's bit-spreading technique, while it improves the data communication by allowing more data to be communicated using otherwise unusable portions of the frequency spectrum, it does have a side effect in that it causes an increase in the peaked-to-average power ratio for PAR of the transmitted signal; second, that increase in PAR is undesirable for a very large number of reasons; and third, that the secondary reference, Stopler, teaches a phase scrambler, which is a well known technique in the prior art for reducing PAR.

So the combination would have been obvious to a person of ordinary skill of the art from these three simple statements.

Because we will be talking about the ordinary level of skill in the art, I'd like to reference what that is. Looking at Slide 5, as we put in the petition, the ordinary level of skill in this art is represented by someone with a master's degree in electrical or computer engineering and five years of experience working with multicarrier communications technologies.

That level of ordinary skill we identified in the petition. It was well supported by the declaration testimony of our expert, Dr. Jose Tellado, who is doing research in this area in the prior art time frame on these very same issues. And his testimony was this was representative of what ordinarily skilled practitioners working with these issues had in the time frame.

Patent owner has not contested this, and so this is an uncontested ordinary level of skill in the art.

Jumping to Slide 4 and looking, just for brief orientation, at Claim 1 of the '158 patent, the technology at issue with these two patents relates -- as we see in the last two stanzas of the '158 patent, the technology relates to modulating or transmitting a bit of data on one --

one bit of data from a plurality of fixed data on a carrier signal and then transmitting and modulating the same bit on a second carrier signal. So the claims recite sending the same bit on these two carriers. And that is exactly what Shively does.

Looking at Slide 7, we have portions of the Shively reference which describes, quote, spreading a single block of data, one or more bits, over multiple channels, close quote. Or alternately stated, the same concept as, quote, modulating a second set of respective carriers to represent redundantly at least one portion of the the data stream, close quote.

So Shively is plainly teaching this concept of transmitting the same bit on two carriers recited in the claims. That is, I believe, uncontested.

As Dr. Tellado explained, however, looking at Slide 8, that transmission technique of transmitting the same bits on multiple subcarriers does have a side effect, specifically it can cause a higher peak-to-average power ratio or PAR.

Turning to Slide 9, patent owner more or less illustrated what this concept looks like. Looking at the graph on Slide 9 from patent

owner's response, we see on the left an example where 25 carriers have all been modulated to carry the same value, the bit value of zero. So they are all in phase. And then when they get summed together to create a multicarrier signal, which we see on the right, that multicarrier signal is, for the most part, a very low power, that it has these occasional excursions. We see these very high peaks occasionally within the signal. And those high peaks, relevant to the low average power level is what is representative or indicative of a high PAR signal.

Turning to Slide 10, as I mentioned, patent owner basically conceded that Shively's technique does lead to high PAR. Looking at the patent owner's response, they acknowledge -- again, this is Slide 10 -- they acknowledge that a high PAR can occur where the same bit or bits are purposely sent in a redundant matter on multiple carriers, which is exactly what Shively was teaching.

Going to Slide 12, the second basic fact, as I mentioned, is that the increase in PAR, which results directly from Shively's technique is undesirable.

As Dr. Tellado explained with his first

declaration -- looking at a portion of that on slide 13 -- a person of ordinary skill in this art, someone with a master's degree and five years' experience, would have been quite familiar with the problems associated with a high PAR signal in multicarrier communications technologies, at least to a number of problems, including the use of components that are expensive, that are inefficient. And when those components are not sufficiently designed to encounter a signal that has a PAR that is greater than they are capable of handling, that can result in amplitude clipping, which causes data transmission errors.

And so because of those many deleterious effects associated with an increasing PAR, Dr. Tellado found that a person of ordinary skill in the art would have sought a solution for that.

Looking at Slide 14, patent owner's expert essentially agreed with all of those points. He noted that a high or increased peak-to-average power ration is associated with components that are expensive and power hungry, that could consume a large amount of power, and in his word were, quote, impractical, close quote.

Dr. Short further agreed, looking at Slide 15, that because of those disadvantages, engineers

would have been interested in using techniques to reduce PAR.

So, so far we have the first two basic observations that I mentioned at the top are essentially undisputed.

Turning to Slide 16, that brings us to my point number 3, and that's that Stopler provides a solution to this problem in Shively in its teaching of a phase scrambler which can reduce PAR.

Looking at slide 17, first I want to clarify there's no dispute that Stopler describes a phase scrambler. It's labeled as such quite plainly in Stopler's figure 5, and it's part of component 82, which is a QAM mapper and phase scrambler.

Turning to Slide 18, Stopler describes the application of that component, which is responsible for, among other things, mapping data into QAM symbols, tone by tone, which references -- tone by tone references the individual carriers or subcarriers equivalently stated, which make up the multicarrier transmission signal. And then Stopler further explains that a phase scrambling sequence is applied to those symbols.

Turning to Slide 19, Dr. Tellado has further explained in his deposition testimony that in the late 1990s, when he was doing his thesis work

on this prior technology and on these PAR issues, phase scrambling -- direct quote from him -- quote, phase scrambling was probably the most popular way, close quote, of reducing PAR. And in his second deposition he reiterated that it was well known when he wrote his thesis that phase scrambling was a technique for reducing PAR.

I want to pause briefly here because this was the central issue in dispute at the time of institution. At the time of institution we had the evidence from Dr. Tellado explaining that phase scrambling was an obvious way to reduce PAR in Shively, and we have attorney argument from the patent owner. Well, we are now nine months later and we have more evidence from Dr. Tellado that not only was i t apparent to know, but phase scrambling was perhaps the most popular way of reducing PAR.

And turning to Slide 20, we have Dr. Short, patent owner's expert, who essentially has no opinion on this. When we asked him whether or not he believed that randomizing the phases of individual carriers was a known technique before 1990 for reducing PAR, the phase scrambling was think was known in the art, his answer was, I don't know. He did not have any opinion one way or the other. He had no basis for knowledge, no testimony

whatsoever as whether or not this would have been known.

So we've got just an increase in disparity in evidence between petitioner and patent owner at this point. We have Dr. Tellado's well informed testimony from his experience, and we have Dr. Short's nonanswer, his lack of evidence, his lack of knowledge, and his lack of opinion regarding this.

So I think the evidence here on this point of obviousness of the combination is even more lopsided now than it was at the time of the institution.

Turning to Slide 25, patent owner has put forward an argument regarding the way that they read Stopler and Stopler's disclosure of its phase-scrambling technique. And patent owner has asserted that Stopler is not scrambling the phases of QAM symbols. But that's not the natural reading of Stopler. But patent owner asserts that Stopler's technique is, instead, scrambling groups of QAM symbols. All of the QAM symbols that would be transmitted together as a single multicarrier signal, that group of QAM symbols in the aggregate known as something called the DMT symbol. But that position was rather directly undermined by their

expert in deposition.

We see here on Slide 25 the highlighted quote from Stopler where it states that the phase scrambler is applied to all symbols. And patent owner's expert in deposition agreed that the reference to all symbols is a reference to QAM symbols. So patent owner's expert agrees that the phase scrambler is being applied to the QAM symbols, not DMT symbols.

If we look at the end of that quotation from Stopler, the last two lines, Stopler is discussing selecting the amount of rotation to be applied to the symbol, singular. If Stopler is applied to all symbols and those symbols are QAM symbols and if an amount of rotation is being applied to one symbol, Stopler is plainly describing applying the phase scrambler, QAM symbol by QAM symbol, tone by tone, carrier by carrier, which, again, was basically a restatement of this well known technique of phase scrambling that Dr. Tellado testified to.

Going to Slide 27 finally, this is back to essentially undisputed issues. Patent owner -- I'm

sorry -- this slide is slightly mislabeled. This is patent owner's expert, Dr. Short.

Dr. Short agreed that by rotating symbols, by changing their phases, you can reduce the peak-to-average ratio, that changing the phases of individual symbols is a technique for reducing PAR. But that is the result.

And so Stopler's description and disclosure of changing the phases of individual QAM symbols is indeed a technique for reducing PAR. And for the reasons that Dr. Tellado explained, especially that it was a very popular and well known technique, would have been obvious to a person of ordinary skill in the art that this was suitable solution to the issue raised by Shively, that Shively, by transmitting the same data on multiple carriers increases the PAR. Stopler then provides the solution for that.

Looking at Slide 28, patent owner's other principal argument is that Shively's technique is applicable only to long lines. And by long lines, the patent owner means lines that are at least

18,000 feet in length.

But that's pretty directly disputed by the text of Shively itself, which states that its technique is applied, quote, to compensate for high attenuation and/or high noise, close quote, in the communications channel. And certainly high noise can occur on a short line. High noise is not necessarily affiliated with a long line. And Shively references that combination of attenuation and noise in multiple places, and in general, looking at the second quote on Slide 28, Shively terms those collectively as impaired parts of the frequency.

And looking at Slide 30, patent owner's expert, Dr. Short, agreed that Shively's technique could be used in general on other kinds of impaired tones, that Shively's technique was not limited to tones that are impaired because of high attenuation, but Shively's technique could also be used where the line or where specific tones or carriers within the frequency spectrum have significant noise.

For that reason they have a very low signal-to-noise ratio. The signal might be strong, but the noise is high as well. So the signal-to-noise ratio is still low. Those impaired tones can still make use of Shively's technique.

Dr. Short agreed.

And then a final point on that, looking at Slide 31, Dr. Tellado further explained that modem designers, engineers working the space, wouldn't be designing a modem that operates only at 18,000 feet. They would design a modem that works at a variety of different line lengths, not just 18,000 feet. They would be looking at a variety of scenarios and a variety of potential issues that a modem might encounter.

If there are no questions, I will reserve the remainder of my time for rebuttal.

JUDGE CLEMENTS: I have a question about Point 2, so back to Slide -- Slide 16 illustrates it. It's an increase in PAR is undesirable, and I think you characterized it as undisputed. But the way I understand patent owner's argument is that it's undesirable only if it results in clipping and that Shively doesn't necessarily result in clipping.

So assuming that's the case, that Shively has a very low probability of clipping, is there some other reason, some other evidence of record of why a person skilled in the art would want to reduce PAR if it's not going to result in clipping anyway?

MR. FOSTER: Yes, there is. I would

direct you, to begin with, on Slide 13, the portion of Dr. Tellado's first declaration, where he references that some of the problems associated with a high PAR signal include components that are expensive and inefficient. And so if a system is being designed where it is known that it could use techniques that would increase PAR that's going to lead to an increase in expense and inefficiency of those components that make up the transmitter, that obviously would not be very desirable.

As I also uncovered, looking at slide 14, Dr. Short generally agreed with that as well, that the high PAR signal or increase in the bar would result in components that are expensive and power hungry, impractical even.

You could also look at Exhibit 1027, which was the deposition of Dr. Short. On page 46 between lines 13 and 19 Dr. Short also referenced that an increase in PAR associated with components that are larger. So not only are they more inefficient, more expensive, more power hungry, they are just physically larger, which could have negative effects.

JUDGE CLEMENTS: Okay. Thank you.

One other question on construing scrambling of plurality of carrier phases. Patent

owner proposes adjusting the phases on a plurality of carriers in a single multicarrier symbol by psuedo-randomly varying amounts. And I think in the reply petitioner says no construction's necessary because Stopler teaches phase scrambling explicitly.

I think we need to construe it because Stopler may have some idiosyncratic definition of phase scrambling. That's a possibility. So I think we'll have to construe it and then determine whether Stopler teaches it.

My question is, does petitioner have an issue with patent owner's proposal? Because both parties -- neither party seems to dispute that we are talking about adjusting phases of carriers within a single DMT symbol. The dispute really seems to be about whether Stopler does that or whether it's scrambling phases from symbol to symbol over time.

So what's petitioner's position on the proper construction of scrambling plurality of carrier phases?

MR. FOSTER: Yes, Your Honor.

Since we didn't put it in the petitioner's reply, we don't think construction is necessary. I understand that you disagree with

that.

Regarding patent owner's proposal of the construction, we believe that is exactly how Stopler is describing his phase scrambler as operating.

JUDGE CLEMENTS: Okay. Thank you.

MR. MCANDREWS: Good afternoon, Your Honors, and may it please the board. I'd like to start with the question that Judge Clements asked of petitioner's counsel because I don't think it quite got to the heart of what the issue is there.

So the question related to whether to the extent that Stopler -- I'm sorry -- to the extent that Shively -- this goes to Shively -- to the extent the that actually doesn't have a problem in the sensitive clips, and if the board were to take that as true, what other evidence can the petitioner point to to show that one to be motivated to go try to solve an alleged increase in PAR problem. But I think that the petitioner and its experts misapprehend what it means to have an increase in the PAR. And this is particularly so given the high level of skill in the art the petitioner would have ascribed to the person of ordinary skill in the art. They would not see words like high PAR and increased PAR and say

that's enough for me to know that there's a problem. Instead, they would want to look at what those are relative to.

So what are those relative to? They are relative to the design criteria that the modem is designed with respect to. So the modem only will have a particular dynamic range given the anticipated signal, and they typically would use a Gaussian estimation of the anticipated signal transmitting on all 250 carriers in the (undiscernible) system of Shively. And they would determine what is the dynamic range that we want our amplifiers to have to ensure that we achieve the clipping rate that the scanner refers to of 10 to the minus 7, or 1 in about 10 million samples.

Petitioner is alleging that simply if you have a signal that somehow increases PAR, you are going to have to change your amplifiers. Well, no, you're not. If it doesn't increase it beyond where those amplifiers would have a problem, the clipping rate is higher than the standard allows, then there is no problem.

It's a discussion of dynamic range where if you are left unbounded with your signal and you

are only attempting to correct for a high part that goes beyond the dynamic range of design amplifiers, yes, that might require bigger amplifiers and more expensive amplifiers.

But the context of Shively and the context of DSL is that you have fixed dynamic range for your amplifiers. You know what it is going in. And then you look at high -- you know, it's relative terms -- high increased PAR are viewed with respect to whether you have a clipping problem.

But the alleged problems that petitioner's counsel pointed to have nothing to do with once you set your design criteria, and I'll get into that in a little bit.

So Your Honor, Judge Clements, do you have any follow-up to that. Did that address the issue?

JUDGE CLEMENTS: What about the other factors that the petitioner pointed to? The -- you know, the expense, power consumption, physical size. Why wouldn't those have been factors that a person of ordinary skill in the art would take into consideration in incorporating -- you know, if they could incorporate this phase scrambling technique and reduce PAR, and it allows them to use cheaper,

smaller, less power-hungry components, why wouldn't they have done so?

MR. MCANDREWS: Well, the baseline for the components again is going to be full power on all 250 carriers using the Gaussian estimation. So the question is, if there is a PAR that exceeds -- that is high enough to exceed that dynamic range at a rate that's higher than 1 in 10 million samples, then you might have a problem. But our position, as we laid out, is that Shively's technique, because it's used for severely impaired loops, it's directed to the severely impaired loops, those loops are going to use substantially less transmit power. There's going to be substantially less transmit power so it actually reduces the PAR while duplicating carriers, yes, will contribute an uptick that is fully negated many times over, many fold, by the reduction on a Shively loop -- you know, an 18,000-foot loop or longer -- where you would be transmitting less than half of the power you ordinarily would.

And I've got a slide here that shows a reduction of total transmit power will also prevent clipping. So while the signal appears to have peaks, those peaks fall far below the clipping threshold, the dynamic range of the

amplifiers. So this idea that you have to increase the size of your amplifiers doesn't apply.

There's also the concept that -- the flip side of that is if you phase scramble -- let's say you take Shively, and even if it doesn't have a clippings problem, you decide that you want to phase scramble to produce PAR, you can't do that. You can't reduce PAR any lower than what it's designed for. There wouldn't be any motivation to do that because you're presumptively, when it's operating in ordinary mode on an unimpaired loop, you're going to have all 250 carriers transmitting fully on all – at their full power spectrum mass. And so you're not going to have that issue. And so the amplifiers will be designed to take that into consideration.

JUDGE CLEMENTS: Did I understand you to say that the standard requires amplifiers of a certain minimum dynamic range?

MR. MCANDREWS: That would be implementation specific, but the standard does require that the device will clip at a rate that's less than 1 in 10 million samples.

And so what that means, given the power spectrum mass of a given standard -- of the ADSL

standard that Shively's directed to, that would dictate a particular dynamic range.

You design the amplifier to achieve the clipping rate and that dynamic range happens to be -- and both parties appear to agree on this -- that the dynamic range that the amplifiers would be designed to for the ADSL standard is -- the patent talks about 14.5 dB. Petitioner's expert uses a slightly lower one. They use 14.2 dB. But it appears that the parties are in full agreement that that's approximately the design criteria that you arrive at is somewhere in the 14.2 or 14.5 range.

So I'd like to go to my Slide 2, where we summarize these arguments, and I just want to point out that petitioner characterized at least two of these issues as not in dispute, and they fully are in dispute. I mean Shively does not have a power problem. There's no doubt we presented evidence of that. And the parties spent quite a bit of time and energy debating that issue.

So we absolutely do debate that Shively has a power problem. It does not cause clipping at a rate that's greater than the standard allows. And again, even if the duplicated carriers cause

some small uptick, that's negated by the substantial reduction of overall power that the Shively transmitter will transmit.

The second issue is that one with skill in the art, even if Shively had a power problem -- and it does not -- but even if Shively had a power problem, it would not look to Stopler. In fact, it would not look to any phase-scrambling techniques as I'll explain in a little more here.

Part of the difficulty we had is that petitioners did not provide any evidence with their petition, other than the say so of their expert, that phase scrambling was a technique that was known to those with skill in the art for solving PAR issues. Instead, they just took it as granted that they were going to jump to Stopler.

Stopler itself doesn't mention PAR anywhere. If it's not addressed to PAR in any way, shape, or form, it doesn't -- it doesn't in fact describe any issue that would cause a PAR problem. So one with skill in the art is not naturally looking to Stopler if he thinks he's got a PAR problem.

Instead, what petitioner did is they backfilled in their reply with some new references that we've objected to. Those new references

describe phase scrambling techniques that I'll explain in a minute, why those are not only totally incompatible and contrary to the purpose of Shively, but they would not solve the PAR problem of Shively. And I'll get to that in just a minute.

So just very quickly, and this is more for the record -- I'm sure Your Honors understand the technical basis of these terms -- but peak-to-average power ratio, of course, is the instantaneous peak of a signal compared to its time-average value.

Typically when you are going to look at a figure like we have on Slide 4 -- I'm now on Slide 4 -- what you are looking at there is the signal over a DMT symbol. So over a single period you're going to have peaks and valleys, you are going to have an average in the signal over that DMT symbol period. So this is power over time. And what we're looking at here is the symbol. And the symbol, what it shows, is we've got a single peak that reaches the red line. And so that would be a peak of the signal, and we've got an average that's the black line.

On Slide 5 Dr. Short discusses the issue of what causes clipping, and that's when the peaks exceed the clipping threshold. This is where they are going to be exceeding that dynamic range of approximately 14.2 to 14.5. And these are samples of a symbols. These are the sample of the DMT symbol over time.

You may have noticed that the parties, when they were describing the sampling rate, patent owner originally used what the patent was describing, that it was a clipping rate per sample. The petitioner, when they put in evidence in the reply, they used a clipping rate of a symbol, which is, instead of 10 to minus 7, is about 5.1 to the minus 5. Just so we know that we're talking about the same clipping rate.

So the clipping rate of the standard is 10 to the minus 7. What this slide is also pointing out is that there's only a PAR problem when the peaks exceed the maximum dynamic range and clipping is caused.

On Slide 6 we see that Dr. Short provided some declaration testimony about this issue, and the patent also refers to this 1 times 10 to the minus 7 clipping threshold, and it also mentions the dynamic range that an ADSL

transmitter would typically use. That's 14.5 dB. And that's found on Slide 6 in the excerpt of the patent on the lower right-hand side.

JUDGE JEFFERSON: Counsel, can you go back to Slide 5. You have an excerpt from the patent that describes that increased PAR can result in a system with high power consumption and/or clipping.

MR. MCANDREWS: Yes, Your Honor.

JUDGE JEFFERSON: Just drop the and/or. Why isn't just the potential for a high power problem sufficient to want a low PAR?

MR. MCANDREWS: So again, it would only be high power consumption if in fact the amplifier was, first of all, was designed to allow that. So if you're going to clip you are probably not going to send the signal anyway, so you're not going to have high power consumption.

But if you redesign your amplifiers to have to achieve a higher peak -- a higher dynamic range, then that could be -- that could cause higher power consumption. It could also cause more cost in the system. But the point here is that that doesn't have to be done when your signal, whatever your signal may be, when your signal is not exceeding 14.5 dB or 14.2 dB. And

what we pointed out with Shively is that it will not achieve that. It will not exceed the 14.2 dB or 14.5 dB at a rate that's greater than is allowed by standard. So there would be no need to bring in bigger amplifiers.

JUDGE JEFFERSON: Then there's no high power problem and there's no clipping problem.

MR. MCANDREWS: There's no high power problem and there's no clipping problem when the signal itself has a lower PAR. The signal itself will have a lower PAR in Shively's technique on an 18,000 foot loop.

JUDGE JEFFERSON: Would it have a high power problem on a shorter loop?

MR. MCANDREWS: On a shorter loop -- so let's take the issue of the 12,000 foot loop. And again, as you know from our papers, patent owner maintains that there's no basis for using Shively on a 12,000 foot loop. Maybe I should address that, for example, here.

JUDGE JEFFERSON: Before you address that, would there be a high power problem if there was a shorter loop, setting aside there's no basis for that.

MR. MCANDREWS: So the answer to that question is depending on -- so the answer is if you

were to blindly use Shively's spreading technique on a scenario that they cherrypicked -- so let me address -- I'm sorry. Let me address the 12,000-foot loop.

So on the 12,000-foot loop, the scenario that petitioner chose in its reply brief, that does show that there would be an issue with clipping. The clipping rate would exceed 10 to the minus 7. However, one with skill in the art, first of all, would recognize that any other loop shorter than that -- say, 9,000-foot loop, 6,000-, 3,000-, less-than-10-foot loop, these are all -- by the way, these are all the loops that are addressed on one of the slides -- on one of petitioner's slides. On all those loops, on loops that are shorter than 12,000 feet, there is no PAR problem because Shively's technique is not usable. Those are loops where all of the carriers are going to be fully usable using one bit per carrier.

Now, let's take the 12,000-foot loop. And let me point out one thing that they ignored with the 12,000-foot loop. While they paid lip service to the idea that you need to take into consideration not just attenuation but also noise, their scenario that they rely on to attempt to

show that there's a PAR problem with the 12,000-foot loop ignores noise. If they hadn't ignored noise -- and by the way, they use a lot of paper to show those noise scenarios -- that the ADSL standard wants you to take into consideration, if you use any one of those, what it's going to do is it's actually going to reduce the transmit power because more of the carriers will be unusable.

So what they did is they cherrypicked the scenario -- 12,000-foot line with no noise on it -- to come up with -- and we read testimony from Dr. Tellado that he picked -- he says, I picked that combination to justify my opinions. In hindsight he started with the idea that he was looking for a problem. He started with the notion that he needed to find a problem. So he went to a 12,000-foot loop.

So to back it down, yes, there could potentially be a problem on a 12,000-foot loop. However, let me point out an issue. So Shively is directed to squeezing through a few additional bits on a severely erred line -- a severely impaired line like an 18,000-foot line. And again, there's only a few additional bits that's getting through.

Let's kind of just take it in terms of magnitude. On a 12,000-foot line, you are going to be getting through somewhere on the order of a thousand bits, a thousand bits cleanly on your fully usable carriers. The Shively carriers are going to add a very small, almost de minimus bonus to that. They are going to add, even under petitioner's most rosy view of how you would do that to wind up with 32 Shively carriers. So that's eight groups of four. And then they used a four QAM on those rather than one bit per four that (undiscernible) talks about. But they put two bits on each of those. Even under that you are going to get through only an additional 16 bits per symbol. That's a de minimus gain.

So here's what one with skill in the art would have done. To the extent that one skilled in the art was even thinking of the concept of increased PAR, what they would have done on a 12,000-foot loop, they would have shut off the Shively carriers. There's no reason to use those carriers. If you use those carriers you cause a PAR problem. If I don't use them I've got plenty of bandwidth anyways.

Shively is directed to those loops that are heavily impaired like the 18,000-foot loop,

where you are only allowed to use about 34 percent of your carriers to get data through. And even those carriers, by the way, because of the long loop, those have a signal-to-noise margin that is substantially below those same similar carriers who would have downed the 12,000-foot loop.

And as Your Honor may understand, when you have a -- in the DSL system when you have a the higher signal-to-noise ratio margin available to you, you can put in more bits. You can use a higher order of QAM constellations and put many more bits.

So what Shively is really directed to is those loops where even on your carriers we can get a bit through, you are putting through fewer bits. And so the Shively carriers give you meaningful bonus bits. So on those lines where the Shively carriers are meaningful, you don't have a PAR problem. On the 12,000-foot loop where Shively carriers are meaningless and you wouldn't use them, the more likely thing that one skilled in the art would do is turn them off, turn off the Shively carriers.

And let me mention -- so let's say they decided not to turn them off. Let's say if you wanted to go solve that PAR problem, and for some

reason he thought that he ought to use phase scrambling to do that. Well, Dr. Tellado himself -- and I'm sorry I'm going to jump all the way to slide 58 for this. Slide 58 is the last slide in the deck. Dr. Tellado himself tells us why one with skill in the art on a 12,000-foot loop would not use phase scrambling.

First of all, Dr. Tellado in his thesis, his PhD thesis that is of record, mentions at least half a dozen ways to reduce PAR that don't involve phase scrambling.

Here, in his patents dated in 1998 -- so this is in the prior art; this is in the record; we presented this to Dr. Tellado in his deposition -- he criticizes phase scrambling because he says the randomization scheme requires extra bandwidth.

Okay. So if your phase scrambling scheme is going to require the use of extra bandwidth -- and the reason why there's extra bandwidth is because these phase scrambling techniques, they need to transmit additional information to the other side to let the other side know how to descramble what was just scrambled, we need to tell them what scramble patterns were used or if it was scrambled or it

wasn't scrambled. Some of them actually have to retransmit a symbol. So this is the extra bandwidth that phase scrambling will use. Dr. Tellado points out that that's a big downside in using phase scrambling.

So let's go back to Shively. Shively is on a 12,000-foot loop. He's going to squeeze through a de minimus additional amount of bits. And then he's going to try to solve that problem using a technique that eats up those bits that he just got through. It just doesn't make sense at all. I mean this is pure hindsight to try to jam a phase scrambling technique into Shively. It just doesn't make sense.

The additional thing that would happen if you did that, granted let's say you are going to try to get a few extra bits from Shively and then you would have to give them back with a randomization scheme. In doing that you've added two layers of complexity to your modem. So now you're going to do something with Shively. You're going to use a unique way of spreading bits and then you're going to, as Dr. Clough (phonetic) also points out, he says -- well, one thing he says is peak-to-average, PAR, ratio isn't effectively reduced by phase scrambling. But the

other thing he points out is that it requires an additional IFFT.

An IFFT is like the main engine of the multicarrier communications. It's the modulator that takes in all the multiple carriers and creates a transmission signal out of it. So you're going to add two layers of complexity just to get a de minimus or no gain. So that doesn't make sense.

There's a reason why the 12,000-foot scenario they presented had to be cherrypicked, and they didn't consider all the reasons why one skilled in the art, even given that 12,000-foot-loop scenario, would have gone to phase scrambling.

JUDGE CLEMENTS: Counsel, that sounds like an argument that the phase scrambling may not have been the best way to reduce PAR, at least at the time Dr. Tellado's patent was written, but even here it says randomizing has been shown to somewhat reduce peak-to-average power ratio to an extent.

So doesn't that still support petitioner's notion that phase scrambling is a way of reducing PAR, even if it's the not the best way?

MR. MCANDREWS: So it's a way. It may do

it to an extent. But if it's not sufficient to do it fully, it may not be usable with Shively to the extent that you are going to use Shively in this manner to cause a PAR problem. And again, I don't think you would. You would not use Shively at all when you have plenty of bandwidth.

The other issue, though, is that I pointed out it's not just that it's -- it doesn't fully effectively reduce PAR. I pointed out that it's actually incompatible with Shively's goal of squeezing some additional bandwidth out of these impaired carriers because it actually requires additional bandwidth to do the scrambling in the first place. So it's going to negate that benefit. It's not just that it's not a great way, it's that it's a way that would negate the benefit of Shively and therefore be incompatible.

The other thing that I want to mention, though, this was the petitioner's burden to show, and the petitioner failed to address any of these things that I was just talking about. They just -- they just assumed that Shively has a PAR problem. We demonstrated that it doesn't, given Shively's primary application to impaired loops. And then they just presumed in their petition that you would run off and grab something that doesn't

describe solving PAR, you know, Stopler, and they claim that does some aspect of phase scrambling.

So does that answer your question, Your Honor.

JUDGE CLEMENTS: It does, and actually it brings me to another question about the 18,000 foot scenario. Assuming you're right and it results in power levels of I think -- is it 40 percent in normal mode and 49 percent in power boost mode -- isn't it the peak-to-average ratio that's important? And so even if the ratio -- I mean even if the average, in the denominator, goes down to 40 percent or 49 percent, how does it follow necessarily that the ratio therefore is not problematic? It seems to me that that just means that the peak could be up 40 percent lower, or 49 percent lower, and you'd have the same problematic ratio.

MR. MCANDREWS: Well, so I actually -- as is shown by the simulations that Dr. Clough put together. They actually showed that when you reduce the number of carriers that you are using, it actually does reduce the PAR. In fact, the peak-to-average is reduced.

But I would also point out that while the peak-to-average is reduced, it's really the peak that you are most concerned with. The

peak-to-average is not much of a concern as long as you are within the dynamic range that the amplifiers allow.

JUDGE CLEMENTS: Well, the problem is, when I read the '243 patent, you know, the background of invention, for example, talks about the PAR itself being a problem to be solved, not the absolute value of the peak.

MR. MCANDREWS: Your Honor, I don't disagree with that. I believe there are some loose usage of the term PAR in the background section, but one skilled in the art would get to the portion where they talk about clipping rate and dynamic range and understand that what they're talking about is increases in PAR and increases in clipping -- or increases in PAR that would cause clipping. So it's not simply the peak-to-average that's the problem. You have to look at the whole signal and determine whether you can meet the design criteria of the DSL standard.

I would also point out that the background section of the patent owner's patent is not prior art. It's describing what they view as problematic issues in the prior art, not necessarily what one of ordinary skill in the art would have known prior to reading the background

section.

JUDGE CLEMENTS: Okay. Thank you.

MR. MCANDREWS: So let me -- it sounds like we have a fairly good understanding of the issue of what Shively presents and whether there's a PAR problem or there's not.

So just going back to Shively, and now I'm on Slide 10, I just want to point out that Shively talks about severely impaired lines of the 18,000 feet or more. And petitioner raised this issue that we didn't take into consideration noise. That's actually not true. The curves that we used to simulate and to determine whether Shively has a PAR problem take into consideration both attenuation and noise. And I would point out that Shively himself was talking about noise that is particular to long lines. The quote at the bottom of Slide 10 from column 11, lines 11 and 12, from Shively said such noisy and/or highly attenuated sub-bands can occur, for example on long run severely impaired conductors.

And so what they are talking here is really problems that are unique to these long lines. Yes, there's higher attenuation and yes, there's -- there may be higher noise associated with these lines, but they are really talking

about the cumulative effect of noise and attenuation of these long lines where attenuation is going to be the primary contributor to the impairment of a line.

I think that -- and so going to Slide 11, I think it sounds like there's a very good understanding of what Shively teaches. The purple-shaded carriers in the annotated version, figure 1, those are fully usable carriers. Those are carriers that can carry at least one bit. And then multicarrier system like DMT, ADSL, some of those carriers will carry more.

The yellow-shaded carriers are carriers that the parties have called either impaired, partially usable Shively carriers, those are the carriers over which information is spread. The idea is that the difference between line -- the green line, which is the attenuation in noise for, and the blue line -- the blue line is the margin necessary to transmit at least one bit. When we get into the yellow-shaded carriers, there's no longer sufficient margin below the red line. The red line is the transmit power spectral maximum, you know, so it's a mask. And so what Shively does is he's going to use what margin is left and combine that margin for multiple carriers to get

individual bits across.

So what petitioner failed to take into consideration in their petition, though, is that it's not just the Shively spreading technique, but they failed to take into consideration -- well, they fail to take into consideration the design criteria that we talked about.

The design 14.2-14.5 dynamic range that is presumed, and then given that they failed to take into consideration that Shively will be addressed in many unusable carriers. The figure there shows the green line running all the way to the red line. And what will be understood from that figure is that carriers to the right of that, carriers at higher frequencies, would be totally unusable. They have no margin left to contribute to the spreading technique. That's shown on Slide 13. Dr. Short explained that, that there would be an additional group of carriers to the right.

On slide 14 we can see that Shively was cognizant of this issue because he was talking about signal attenuation at higher frequencies where that's greater than 500 Kilohertz. What he was -- he was doing that in referencing his figure 1. What he was explaining is that figure 1 was showing that it's at about 500 kilohertz where

you're going to run into this problem where you don't have sufficient signal-to-noise margin. And then you're very quickly going to run into carriers where you have no margin.

And so just a quick background point, the ADSL standard has about 250 carriers and they are spread between 30 kilohertz and 1.1 megahertz. And so if you are cut off of usable carriers at about 500 kilohertz, that means that fewer than half of your carriers are available to be used.

And so jumping forward to slide 17, this is exactly what Dr. Short's analysis was. He took a typical attenuation curve for an 18,000-foot loop and he identified, based on signal-to-noise margin, which carriers would be usable, which carriers -- I'm sorry -- which carriers would be fully usable, which carriers would be usable for a spread technique, and which carriers would be totally unusable. And he concluded that 34 percent are unimpaired and fully usable, 6 percent could be used for Shively spreading. So 60 percent would be totally unusable.

And so what that means, because you have a power spectral mask in normal mode where all

carriers are limited to the same amount, when you can't use carriers, you don't transmit any power there. So what that means is that your signal -- total transmit signal would be dropped by 60 percent. And what that leads to, as pointed out in the testimony on Slide 18, is a substantially reduced clipping rate.

And I've presented only the normal mode. Judge Clements, you mentioned there's a power-boost mode that will lead a slightly different result.

Petitioner, when they came back and replied, they didn't address the power boost mode, so I've limited my presentation to the normal mode. There's not -- there's no significant meaningful difference. We were just showing that, given the full disclosure with Shively, there would be no clipping problem either in the power boost or the normal mode. What we see is that the clipping rate is substantially many orders of the magnitude below that allowed by the standard.

Now, petitioner has criticized Dr. Short's analysis. They criticized him for using a Gaussian analysis. And so what do they do to criticize that?

Well, one thing they did is they put in

some information -- and I apologize, let me jump forward to Slide 22. So Slide 22 shows essentially a statistical analysis of how often Shively carriers are going to align. However, this doesn't take into consideration the fully usable carriers. It doesn't take into consideration the design criteria, the clipping rate. It doesn't take into consideration the dynamic range of the amplifiers. It doesn't take into consideration the completely unusable carriers. And by his own admission, as we see on Slide 23, quantifying the effect of the PAR would have called for running numeric simulations. And he certainly wrote a map lab program to check these to determine whether a given scenario presented a PAR problem. So he effectively admitted that his statistical analysis was really irrelevant to the issue.

So they didn't -- so what -- so I guess I go back to the question. What did they provide to criticize Dr. Short's analysis? They actually provided nothing that was relevant. By his own admission he had to run a simulation, but Dr. Dr. Tellado apparently ran an 18,000-foot simulation and then discarded or lost or overwrote those results.

And that was the subject of a motion. As Your Honors know, we had requested that the petitioner turn over the 18,000-foot simulation that the Dr. Tellado had agreed that he had done during cross-examination. They refused to turn it over, and they claimed that it wasn't routine or additional discovery. We believe it is. We believe that, first of all, it was relied on. He mentions it in his cross-examination testimony as a reason why he thought that Dr. Short's analysis was flawed. It's also obviously going to be inconsistent with their opinion that Dr. Short's analysis is wrong. Dr. Short's analysis shows that there is a many-order-of-magnitude reduction in the clipping rate on an 18,000-foot loop.

And so I don't know whether I'm supposed to be addressing that motion here. It was filed. It hasn't yet been ruled on. I suspect it will be ruled on with the final written decision. But I just want to mention that I think that an appropriate remedy at a minimum would be to provide an adverse inference. The 18,000-foot-loop simulation that they lost would have supported Dr. Short's position that there is no clipping problem on an 18,000 foot loop.

A more appropriate remedy --

JUDGE CLEMENTS: Even assuming Dr. Short's analysis is correct and it would not have been advantageous on an 18,000-foot loop, does that matter if it would have been advantageous on a 12,000-foot loop?

In other words, why wouldn't the advantages on a 12,000-foot loop have been sufficient to motivate a person of ordinary skill in the art to make those combinations.

MR. MCANDREWS: So Your Honor, as I pointed out before, the advantage of using Shively spreading is de minimus. There is no -- there is effectively no advantage to using Shively's spreading technique on a 12,000-foot loop. It wouldn't be used because there's a de minimus number of bits to get through in addition to the high number of bits that are getting through on fully impaired carriers. So there's no advantage.

And then to the extent that there is a downside to that speaks to one skilled in the art would have recognized, would have cherrypicked -- this 12,000-foot noiseless scenario that Dr. Tellado started with as his premise of how he was going to justify his opinion, if they recognized that there may have been an uptick in PAR -- and we maintain this is not what one

skilled in the art would have done -- they would have looked at Shively and they would have understood we're transmitting on substantially fewer carriers -- there is going to be no PAR problem.

But if they cherrypicked the scenario, they would have recognized the simple thing to do was just not transmit Shively carriers. They just don't because there is no -- there's not a benefit enough to justify the complexity that would be required to undo that benefit. If they recognized there was a PAR problem.

So our position is that they've cherrypicked this one scenario. Again, 9000-foot loop -- 6-, 3-, put noise on a 12. They're not going to be able to show there's a PAR problem.

He approached the problem with hindsight that he wanted to find a problem, and he was able to find one. And that's the only simulation they provided. They provided one single simulation. Dr. Tellado says, oh, I could have done many. Well, he didn't do many. He did one that he cherrypicked to try to show that there was a problem. All the other ones in particular that Shively is directed to, 18,000 feet or longer, those all would have definitely had no PAR

problem.

But as I was about to say, I should think the more appropriate remedy for hiding the evidence that would have been contrary to their position and would have shown the other side of their 12,000-foot-loop-cherrypicked scenario is to exclude their evidence on the 12,000-foot loop. This was evidence that was provided for the first time with their reply. They should have but did not do any form of rigorous analysis of Shively in their petition as they should have. You know, Dr. Tellado says these are the sorts of simulations one that is skilled in the art would have done. Well, they knew that at the time their petition was filed. Why didn't they put it in there? Why didn't they address it then? They waited. They waited and then they cherrypicked a solution and they held back the one that would have helped us.

But I actually think the more appropriate remedy here would be to exclude any evidence of the 12,000-foot loop simulation.

Now, how do we know -- and this is evidence, Your Honor, that I will freely admit is not of record. So Slide 24 is a simulation

performed by our expert using Dr. Tellado's mat map simulation.

JUDGE MEDLEY: So this isn't in the record at all?

MR. MCANDREWS: Your Honor, it's not in the record. It's not in the record.

JUDGE MEDLEY: Then we don't want to hear it.

MR. MCANDREWS: Well, petitioner did not object to it, and I think what they may be trying to do here is hedge their bets on whether you will provide a remedy on our motion for additional discovery and our motion to exclude the sanctions effectively that I just mentioned. So it appears that they want to allow this into the record.

Your Honor, what I can do is, if you have a problem with this slide -- because I will admit, as I pointed out, it's not in the record -- I can go to Slide 26, which shows effectively the same thing, which is in the record. This was presented in the cross-examination of Dr. Tellado, and it shows effectively the same results. So maybe I'll do that. I pointed out --

JUDGE MEDLEY: Yeah. Let's stick with what's in the record.

MR. MCANDREWS: Okay, your Honor. And I

understand the resistance here. But it's in part because we don't yet know what the board is going to do with they 18,000-foot-loop scenario.

For example, had the board granted our motion for discovery, we would have been able to put that simulation that Dr. Tellado did into the record, although maybe it sounds like it doesn't exist anymore. We would have been able to put it into the record. But we can't. So what I have instead is I have a simulation that is -- that was done by -- according to Dr. Tellado on Slide 26 and present it to Dr. Tellado. Dr. Tellado refused to talk about whether it was accurate or what it showed. But what it shows is that scenario five is actually the 18,000-foot-loop scenario. And what it is showing is that there is a substantially reduced chance of PAR that the Gaussian line and the 250 QAM carrier scenario, the one and two on the slide, those are showing the design criteria. And the way you figure out the design criteria is you follow that line to 5.1 to the negative 5. And where that crosses is at about 14.2 dB. This is the analysis that petitioner's expert did.

And so what you are looking for is where scenario five, that line will cross 14.2 dB, and

as we can see, it will cross it far below the graph. And the reason why we don't see where it crosses -- and this is something that we determined in trying to do this scenario is in order to get that line to run all the way to 14.2 dB, it would have required a computer, a very fast computer to run for over 15,000 hours. That's -- it is actually generating symbols. It's generating real symbols. And it's generating them faster than DMT system would do. But it's generating them at a high rate. But even so, it would have taken almost two years to show where that line crosses.

What that does is further demonstrates how low the chance of clipping would actually be. And where it's going to cross is it's going to cross -- this is an estimate -- it's going to cross about seven orders of magnitude below the allowed clipping threshhold.

JUDGE MEDLEY: Thank you. You're out of time.

MR. MCANDREWS: Yes. Thank you, Your Honor.

MR. FOSTER: Thank you, Your Honors.

There's a number of points that patent owner raised that I'd like to respond to. The

first, at one point patent owner mentioned you can't do better than Gaussian, and that's simply not true and it's quite relevant to a number of issues that patent owner brought up.

I'd like for us to look at -- this is Exhibit 1026. This is Dr. Tellado's second declaration, paragraph 4, where he states that indeed PAR reduction was an active area of research in the 1990s, and that really what engineers were trying to do is they were trying to beat Gaussian. They were trying to get better performance than what a Gaussian distribution would provide. And that's what his research topic was on. That's what his patent is about. It's a technique for doing much better than simply randomizing, being very intelligent about the way that you manipulate the signals so you can get better-than-Gaussian performance, even lower PAR than simply randomizing, which is all that's being done and discussed in the '243 and the '158 patent.

And so that then explains part of the reason why Dr. Tellado's patent had the comments that it did about phase scrambling. Those comments were really about phase scrambling as it was being performed in the research, where they

would perform phase scrambling multiple times. And when you perform it multiple times and then choose from among those four, eight, or twelve different scenarios, whichever one has the lowest PAR, you can see that you could reduce the PAR because you are always sending with the lowest of random set. That's what produces the side information that his patent describes.

That's the side information that has to be transmitted. None of that is required with the is technique Stopler is describing. Stopler isn't trying to beat Gaussian. Stopler is just randomizing once.

And as Dr. Tellado explained in paragraph 4, if you only do phase scrambling once, what you get is Gaussian performance, and you don't need to transmit any side information.

The reasons why they are addressed in some of the deep claims in the '158 patent that relate to synchronizing the pseudo-random number generators that each of the transmitter and the receiver are using to generate these phase scrambling values. The pseudo-random number generator gets synchronized and then they won't need to transmit any information. The random number generator is proceeding in sync so that the

same pseudo-random numbers are generated independently of one another on both sides. There's no side information, no extra bandwidth needed.

So Stopler's solution, again, doesn't have some of the disadvantages that Dr. Tellado was describing with some other more advanced phase scrambling techniques that were disclosed in the prior art.

Patent owner also brought up an argument relating to whether or not a person of ordinary skill in the art would even use Shively's technique. They said, Well, if a line already has substantial bandwidth, then you wouldn't even use Shively's technique. You would turn off the, quote/unquote, Shively carrier.

I think it's important to note that Shively is not the secondary reference here. The question is not whether it would be obvious to add Shively's technique to Stopler. Shively's the primary reference.

The obviousness question begins with the assumption -- with the premise that Shively's technique is being used because Shively is the

primary reference and he's describing a transmitter that's using its technique. Shively doesn't disclose within it an idea of potentially not using this technique, of turning off its redundant carriers for some scenario. It presumes that its technique is being used to the extent possible to maximize the amount of the bandwidth and data through put that can go down the telephone wire.

Another point, and this is a key one that patent owner brought up. Regarding the 18,000-foot scenario, patent owner is essentially assuming that the transmitter is designed to operate on any length line, that the transmit is designed to handle all 256 carriers that might be available in an ADSL system. But that modem designed for 256 carriers is only being used on a line that's at least 18,000 feet.

I pointed out -- everybody agrees that one way to address a PAR problem is to design -- to describe a better transmitter, to design a transmitter that can handle a higher PAR signal. Well, that's essentially what patent owner is assuming is happening. You've taken a scenario where you are only going to be using less than half the carriers. You are going to design a

modem that handles all of them.

Well, that doesn't make any sense. The patent owner's mixing and matching scenarios, assuming a modem that's capable of 256 carriers but then only using it with half. So that's an apples-and-orange assumption that they're trying to make by saying a modem designed to work with 256 carriers will not cause clipping under the analysis that Dr. Short did with Gaussian approximation. That's just not the correct analysis. It's the wrong set of assumptions. If a modem was going to be designed only to operate at 18,000 feet, then it would only be designed to work with the carriers available on the 18,000 feet.

Regarding the Gausian approximation, Dr. Tellado in his second declaration did not attempt to quantify the amount of error in Dr. Short's analysis. Dr. Tellado did not identify how wrong Dr. Short was. Dr. Tellado's opinion was simply that his analysis was not right because he's treating Shively's technique and Shively's carriers that are not random. He's treating them as random. And the analysis that Dr. Tellado provided, which was the basis for his opinion that Dr. Short's analysis was flawed,

fully supported that and didn't require simulation.

Simulation is -- as patent owner pointed out, simulation is required to quantify something. But to just show that Dr. Short was wrong didn't require running simulation. It's kind of like saying do you know what the square root of 17 is? Do you know that it's 4? If I said the square root of 17 is 4, you don't need to do the math to find the answer to know that I'm wrong. You have to do math to find out how wrong I am. Dr. Short in this case was wrong. That's all that Dr. Tellado explained in his second declaration.

Finally, regarding patent owner's slide 26, where they showed the analysis they performed using Dr. Tellado's map lab code to produce the graph that's in Exhibit 2011, we have that graph in Exhibit 2011. Their graph includes this new scenario, scenario 5, which was added to the original scenarios 1, 2, 3, and 4 that were produced by Dr. Tellado's original analysis based on the 18,000-foot loop.

The fifth scenario is for 88 QAM carriers and 16 Shively carriers. That roughly corresponds with that -- those are the numbers that Dr. Short came up with with his analysis of

an 18,000-foot loop. What's not shown here is what would happen on a 18,000-foot loop without Shively.

Patent owner apparently did not want to put that line in because it would have shown and confirmed Dr. Tellado's testimony that adding Shively carriers to a system increases PAR. I believe that line would have been to the left of the black line that they have for the 18,000 loop including Shively carriers.

But patent owner didn't put that in. And then regarding Dr. Tellado's reluctance to testify or explain or answer any questions about this graph, the source code that patent owner provided in conjunction with this during deposition, Dr. Tellado immediately recognized and included additional changes that patent owner had not recognized or pointed out to him. Additional changes to his code that essentially weren't acknowledged.

And then also when we asked him on redirect questions about this, he confirmed that in fact the code that patent owner provided and said what produced this graph could not have produced this graph. The code that patent owner provided didn't have five scenarios. It had four

scenarios. And so the code for this graph has not been disclosed, and I think Dr. Tellado was right not to opine about a graph where he didn't know where it had come from.

Patent owner also made a few statements suggesting that Dr. Tellado's analysis of the 18,000-foot loop was -- essentially the results are (undiscernible), patent owner is saying that he picked the scenario to prove a point that it was preordained, and he's using hindsight and other things. And that's simply not consistent with Dr. Tellado's explanation for how he arrived at the numbers that he used with the simulation.

And Dr. Tellado also explained that the simulation he provided on the 12,000-foot loop, the numbers that go into that, the simulation, are simply the number of carriers that have either a random QAM four symbol or are being used in a Shively group. And any number of combinations of noise and attenuation can result in those same number of carriers being available.

So Dr. Tellado used Exhibit 2009, patent owner's graph showing examples of attenuation curves for ADSL with essentially no noise, the lowest background noise that might be expected. He used that because that was essentially the

patent owner's evidence that had been put in regarding how these lines look to a modem, what their attenuation curves look like, ignoring that, as he explained, a real line would potentially have many noise sources that could influence those graphs and make a line that's 9,000 feet long which might have lower attenuation and have high noise, and it might behave more like a 12,000- or 15,000-foot loop in terms of the number of available carriers, either from random data or that might be used with Shively's technique.

So Dr. Tellado was not cherrypicking as patent owner asserted. Dr. Tellado was showing an example of many to dispute patent owner's assertion that Shively doesn't ever cause (undiscernible).

And then finally, Dr. Clements, to go back to your first question regarding some of the problems that a high PAR signal can have, I'd also direct you to Exhibit 2002, which was the deposition, first deposition of Dr. Tellado, page 19, lines 10 through 22, and starting with line 19 answering a question about some of the problems with high PAR signals. He explained, quote,

Multicarrier signals have high PAR which makes building the transmitter complicated. And the worse you make it, the harder it is to make a transmitter. Close quote.

So in addition to all the other problems just the design efforts required to deal with the high PAR signal in addition to being more expensive and less efficient. It's more difficult and more involved to deal with a high PAR signal from an engineer's perspective.

If there are no regulate questions -- thank you.

JUDGE MEDLEY: Thank you very much for your presentations and we are adjourned.

(Whereupon, at 4:17 p.m., the proceedings were concluded.)

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Paper 40
Entered: October 26, 2017

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Cases
IPR2016-01020 (Patent 9,014,243 B2)
IPR2016-01021 (Patent 8,718,158 B2)[1]

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and, MATTHEW R. CLEMENTS, *Administrative Patent Judges.*

MEDLEY, *Administrative Patent Judge*.

DECISION
Dismissing Patent Owner's Motion for Additional Discovery
37 C.F.R. §§ 42.51(b)(2) and 42.71(a)

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[1] DISH Network, L.L.C., Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., have been joined in these proceedings.

TQ Delta, LLC ("Patent Owner") filed a Motion for Additional Discovery in the above identified proceedings. Paper 34 ("”Motion" or "Mot.").[2] Cisco Systems, Inc. ("Petitioner") filed an opposition. Paper 39. In each Motion, Patent Owner requests documents identified in Exhibit 2015. Mot. 1. Exhibit 2015 states the following:

> Patent Owner requests that Petitioner, its expert Dr. Jose Tellado, and Petitioner's IPR counsel produce a copy of each unique version of Matlab simulation code and simulation results (including any full or partial results) for an 18,000 foot loop, including without limitation the simulation code and results that Dr. Tellado testified about during his cross-examination on June 20, 2017. *See* Ex. 2013 at 45:23–47:18.

In our Final Written Decisions, entered concurrently with this Decision, we determine that we need not consider whether, and to what extent, Shively's proposed system causes clipping. The discovery Patent Owner seeks is directed to the parties' arguments with respect to whether, and to what extent, Shively's proposed system causes clipping. Mot. 2–3. The requested discovery is moot in light of our Final Written Decisions.

Accordingly, it is

ORDERED that Patent Owner's Motions for additional discovery in the above identified proceedings are *dismissed*.

[2] Citations are to IPR2016-01021.

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Paper No. 43
Entered: February 1, 2018

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

CLEMENTS, *Administrative Patent Judge*.

DECISION
Request for Rehearing
37 C.F.R. § 42.71

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[1] DISH Network, LLC, who filed IPR2017-00254, and Comcast Cable Communications, LLC, Cox Communications, Inc., Time Warner Cable Enterprises LLC, Verizon Services Corp., and ARRIS Group, Inc., who filed IPR2017-00418, have been joined in this proceeding. Paper 14; Paper 15.

I. INTRODUCTION

Pursuant to 37 C.F.R. § 42.71(d), TQ Delta, LLC ("Patent Owner") request rehearing of our Final Written Decision (Paper 41, "Dec."). Paper 42 ("Req. Reh'g"). Specifically, Patent Owner submits that our construction of "scrambling . . . a plurality of carrier phases" misapprehends or overlooks certain evidence, that Stopler[2] does not disclose "scrambling . . . a plurality of carrier phases," that we misapprehended or overlooked certain testimony, and that we misapprehended that Shively[3] would not have an increased or high PAR. Req. Reh'g *passim*.

For the reasons set forth below, Patent Owner's Request for Rehearing is *denied*.

II. STANDARD OF REVIEW

A party requesting rehearing bears the burden of showing that the decision should be modified. 37 C.F.R. § 42.71(d). The party must identify specifically all matters we misapprehended or overlooked, and the place where each matter was addressed previously in a motion, an opposition, or a reply. *Id.* With this in mind, we address the arguments presented by Patent Owner.

III. ANALYSIS

A. "scrambling . . . a plurality of carrier phases"

Independent claim 1 recites "scrambling . . . a plurality of carrier phases." Independent claim 7 similarly recites "scramble a plurality of

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[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012, "Stopler").
[3] U.S. Patent No. 6,144,696 B1; issued Nov. 7, 2000 (Ex. 1011, "Shively").

carrier phases." Independent claims 13 and 20 similarly recite "scramble[s] a plurality of phases." We adopted Patent Owner's proposed construction in part by construing "scrambling . . . a plurality of carrier phases" to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol." Dec. 6–9. We did not add to that construction "by pseudo-randomly varying amounts" because Patent Owner did not show why that additional language should be included for the broadest reasonable construction of the term "scrambling . . . a plurality of carrier phases." *Id*. Patent Owner argues that our construction is overly broad because it encompasses adjusting the phases of every carrier in the single multicarrier symbol by the same amount. Req. Reh'g. 1–2. Such an adjustment, according to Patent Owner, would not reduce peak-to-average power ratio ("PAR"), which the parties and the panel all agree scrambling must do. *Id.* at 3–5. "The FWD misapprehends or overlooks that, under any proper construction, there must at a minimum be *varying amounts* by which the phases are adjusted within a single multicarrier symbol (*i.e.*, *from carrier-to-carrier*) such that PAR is reduced." *Id.* at 2.

Patent Owner presents arguments not presented previously. We could not have overlooked or misapprehended those arguments presented for the first time in the rehearing request. Importantly, Patent Owner argues now for the first time that for any proper construction "there must at a minimum be varying amounts by which the phases are adjusted within a single multicarrier symbol (i.e., from carrier-to-carrier) such that PAR is reduced." *Id.* at 2. This proposed construction differs from Patent Owner's original proposed construction which included "by pseudo-randomly varying

amounts." Absent from the new proposed construction is the term "pseudo-randomly."

In any event, it is clear from the Decision that we construed the totality of each claim as requiring varying the amount by which the phase of each carrier is adjusted. *See, e.g.*, Dec. 21–24. Accordingly, even if we were to adopt Patent Owner's new proposed construction, it would not change the way we applied the prior art to the claim language as a whole.

B. Stopler's Single-Carrier Embodiment

Patent Owner argues that Stopler's QAM Mapper and Phase Scrambler 82 "must be compatible with single-carrier CDMA" because Stopler teaches that its output can, in one embodiment, be provided to a CDMA modulator. Req. Reh'g. 6. Patent Owner concludes that Stopler's phase scrambling "must have a different purpose than the claimed phase scrambling because [it] . . . cannot reduce PAR." *Id.* at 7.

We addressed this argument and found it unpersuasive. Dec. 18–22. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

C. Allegedly Misapprehended or Overlooked Testimony

Patent Owner quotes page 21 of our Decision and argues that "there are several inaccuracies." Req. Reh'g 8–12. These arguments are based, in part, on a mischaracterization of our claim construction as *requiring* the same amount of rotation of the phase of each of the QAM symbols in a DMT symbol. *See, e.g., id.* at 8 ("First, a DMT symbol cannot be phase scrambled as that term is used in the claims by having its component QAM symbols rotated by the *same* amount."), 9 ("as interpreted in the FWD ('i.e.,

rotates by the same amount, the phase of a plurality of QAM symbols.’).”). Our construction of “scrambling . . . a plurality of carrier phases” does not *require* rotating by the same amount. And as we applied the prior art, to the totality of the claim language, it is clear that we construed the totality of the claim language to require the phases of the carriers of the multi-carrier signal be rotated by varying amounts. For example, our Decision states

> Stopler further teaches that, “a phase scrambling sequence is applied to the output symbols,” including “all symbols, not just the overhead symbols.” *Id*. at 12:25–28. Patent Owner’s expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a “scrambling sequence may be generated by a pseudorandom generator” that generates pairs whose sum “is used to select the amount of rotation to be applied to the symbol,” singular; not “symbols” plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner’s contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a single QAM symbol by that amount.

Dec. 21–22.

Patent Owner also objects to our characterization of Dr. Short’s testimony as “admit[ing] that Stopler does not describe phase scrambling DMT symbols” (Dec. 21 (citing Ex. 1027, 60:11–14)). Req. Reh’g 9 (regarding Ex. 1027, 60:11–14). That testimony is as follows:

> Q. Well, you would agree with me that [Stopler] doesn’t expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

Ex. 1027, 60:11–14. We acknowledge that Dr. Short testified that he *understands* Stopler to be rotating all of the QAM symbols within a

DMT symbol by the same amount, but the point made in our Decision remains: Dr. Short clearly conceded, however, that Stopler does not *expressly teach* applying the phase scrambler to the DMT symbol as a whole. Dec. 21 (citing Ex. 1027, 60:11–14).

Patent Owner also argues that we misapprehended its argument that Stopler would adjust the phases of QAM symbols *over time* in order to reduce narrowband noise. Req. Reh'g 10 (citing PO Resp. 39 ("According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82."). As we noted in our Decision, however, Stopler teaches and Petitioner relies "not just on the scrambling of 'overhead signals, such as pilot tones,' (Pet. 12) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive." Dec. 23.

Patent Owner also argues that we misapprehended its burden by noting that "Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol." Req. Reh'g 10–11 (quoting Dec. 21). Petitioner has the burden of persuasion to prove unpatentability by a preponderance of the evidence. *See* 35 U.S.C. § 316(e); *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1379 (Fed. Cir. 2015). For this element, we explained how Petitioner satisfied that burden based, *inter alia*, on express disclosure in

Stopler. Dec. 21–22. The sentence to which Patent Owner objects merely notes that, even assuming Stopler works as Patent Owner argues in an embodiment with a single-carrier modulator, that does not persuasively rebut the express disclosure upon which Petitioner relies. Accordingly, we are not persuaded that we misapprehended Patent Owner's burden.

Patent Owner also argues it was denied the opportunity to file a sur-reply. Req. Reh'g. 11–12. Patent Owner was, however, granted an opportunity to identify allegedly new arguments and evidence in Petitioner's Reply (Paper 21), and we considered the identified portions when reaching our Decision (Dec. 24 n.7). Although the "listing" format required Patent Owner to be efficient in its identification and required Petitioner to be efficient in its responsive paper, these papers provided "the information necessary to make a reasoned decision" (*Ultratec, Inc. v. CaptionCall, LLC*, 872 F.3d 1267, 1273 (Fed. Cir. 2017)) about whether the arguments and evidence raised in reply were outside the scope of a proper reply.

D. Shively's PAR

Finally, Patent Owner argues that we misapprehended or overlooked its argument that Shively's PAR would not be so "increased" or "high" that it resulted in clipping, as would be needed before a person of ordinary skill in the art had reason to modify Shively. Req. Reh'g 12–15. We addressed this argument and found it unpersuasive. Dec. 27–28. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

Moreover, Patent Owner alleges that "the FWD characterizes Shively as having a 'high' or 'increased' PAR." Req. Reh'g. 13 (citing Dec. 27–28). That is false. Our Decision states that it is undisputed that Shively's

technique "will increase PAR" (Dec. 27–28), but does not characterize Shively as having a "high" or "increased" PAR.[4] Our Decision relies upon page 28 of Patent Owner's Response (Paper 12), which concedes that "Shively's 'spreading' technique will contribute a small uptick in clipping probability." Patent Owner does not dispute, in its Request for Rehearing, Shively's technique *increases* PAR.

With respect to Patent Owner's argument that "there is no PAR *problem* presented by Shively" (Req. Reh'g. 13) and "the only PAR problem in this case relates to clipping" (*id.* at 14), we considered that argument and found it unpersuasive. Dec. 27–28. As we noted, "Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold," "there also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR," and, therefore, "a person of ordinary skill in the art . . . would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping." *Id*. In other words, as we explained in our Decision, Shively's PAR need not result in clipping in order to motivate a person of ordinary skill in the art because we are persuaded such a person would have been motivated sufficiently to reduce PAR by the benefit of being able to use smaller, less expensive, less power hungry components.

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[4] In a sentence summarizing Petitioner's position, our Decision states, "*Petitioner alleges* that Shively's proposed system would have an 'increased' or 'high' PAR." Dec. 27 (quoting Pet. 13–14) (emphasis added). It should be obvious, however, that a summary of Petitioner's allegation is not a characterization by the panel.

II. ORDER

Accordingly, it is it is ORDERED that Patent Owner's Request for Rehearing is *denied*.

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC
Patent Owner

Case No. IPR2016-01020[1]
Patent No. 9,014,243

PATENT OWNER'S NOTICE OF APPEAL

[1] DISH Network, L.L.C., who filed a Petition in IPR2017-00254, and Comcast Cable Communications, L.L.C., Cox Communications, Inc., Time Warner Cable Enterprises L.L.C., Verizon Services Corp., and ARRIS Group, Inc., who filed a Petition in IPR2017-00418, have been joined in this proceeding.

Pursuant to 35 U.S.C. §§ 141, 142, and 319, 37 C.F.R. §§ 90.2, 90.3, and 104.2, and Rule 4(a) of the Federal Rules of Appellate Procedure, Patent Owner TQ Delta, LLC ("Patent Owner") hereby appeals to the United States Court of Appeals for the Federal Circuit from the Decision Denying Request for a Rehearing (Paper 43) entered by the Patent Trial and Appeal Board on February 1, 2018 and the Final Written Decision (Paper 41) entered by the Patent Trial and Appeal Board on October 26, 2017, and all rulings leading up to those decisions.

In particular, and in accordance with 37 C.F.R. § 90.2(a)(3)(ii), Patent Owner identifies at least the following issues on appeal:

- The Board's finding that Claims 1-3, 7-9, 13-16, and 20-22 of U.S. Patent No. 9,014,243 are unpatentable as obvious over Shively and Stopler;
- The Board's finding that Claims 4-6, 10-12, 17-19, and 23-25 of U.S. Patent No. 9,014,243 are unpatentable as obvious over Shively, Stopler, and Gerszberg;
- The Board's claim construction; and
- Any Board finding, determination, judgment, or order supporting or related to the aforementioned issues as well as all other issues decided adversely to Patent Owner in any orders, decisions, ruling, and opinions.

Patent Owner is concurrently filing a copy of this Notice of Appeal with the Director of the United States Patent and Trademark Office and the Patent Trial and

Appeal Board, and a copy of the same, along with the required fees, with the United States Court of Appeals for the Federal Circuit.

Dated: April 2, 2017

Respectfully submitted,

/Peter J. McAndrews/

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CERTIFICATE OF FILING

The undersigned hereby certifies that, in addition to being electronically filed through PTAB E2E, a true and correct copy of the above-captioned **NOTICE OF APPEAL** is being filed by hand with the Director on April 2, 2018, at the following address:

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600 Dulany Street
Alexandria, VA 22314

The undersigned also hereby certifies that a true and correct copy of the above-captioned **NOTICE OF APPEAL** and the filing fee is being filed via CM/ECF with the Clerk's Office of the United States Court of Appeals for the Federal Circuit on April 2, 2018.

Dated: April 2, 2018

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that the foregoing **NOTICE OF APPEAL** was served electronically via email on April 2, 2018 in its entirety on the following:

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Paper No. 41
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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

CLEMENTS, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
Inter Partes Review
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

[1] DISH Network, LLC, who filed IPR2017-00254, and Comcast Cable Communications, LLC, Cox Communications, Inc., Time Warner Cable Enterprises LLC, Verizon Services Corp., and ARRIS Group, Inc., who filed IPR2017-00418, have been joined in this proceeding. Paper 14; Paper 15.

I. INTRODUCTION

In this *inter partes* review, instituted pursuant to 35 U.S.C. § 314, Cisco Systems, Inc. ("Petitioner") challenges claims 1–25 ("the challenged claims") of U.S. Patent No. 9,014,243 B2 (Ex. 1001, "the '243 patent"), owned by TQ Delta, LLC ("Patent Owner"). We have jurisdiction under 35 U.S.C. § 6. This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons discussed below, Petitioner has shown by a preponderance of the evidence that the challenged claims are unpatentable. Patent Owner's Motion to Exclude is *dismissed*.

A. Procedural History

Petitioner filed a Petition requesting an *inter partes* review of claims 1–25 of the '243 patent. Paper 2 ("Pet."). Patent Owner filed a Preliminary Response. Paper 6. On November 4, 2016, we instituted *inter partes* review of claims 1–25 of the '243 patent under 35 U.S.C. § 103(a)[2] on the following grounds. Paper 7 ("Inst. Dec."), 16.

References	Claims
Shively[3] and Stopler[4]	1–3, 7–9, 13–16, and 20–22
Shively, Stopler, and Gerszberg[5]	4–6, 10–12, 17–19, and 23–25

[2] The Leahy-Smith America Invents Act, Pub. L. No. 112-29, 125 Stat. 284 (2011) ("AIA"), amended 35 U.S.C. §§ 102 and 103. Because the '243 patent has an effective filing date before the effective date of the applicable AIA amendments, we refer to the pre-AIA versions of 35 U.S.C. §§ 102 and 103.
[3] U.S. Patent No. 6,144,696; issued Nov. 7, 2000 (Ex. 1011, "Shively").
[4] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012, "Stopler").
[5] U.S. Patent No. 6,424,646 B1; issued July 23, 2002 (Ex. 1013, "Gerszberg").

Thereafter, Patent Owner filed a Patent Owner Response (Paper 12, "PO Resp."), to which Petitioner filed a Reply (Paper 17, "Reply"). Pursuant to an Order (Paper 21), Patent Owner filed a listing of alleged statements and evidence in connection with Petitioner's Reply deemed to be beyond the proper scope of a reply. Paper 22. Petitioner filed a response to Patent Owner's listing. Paper 29.

Patent Owner filed a Motion to Exclude (Paper 28), Petitioner filed an Opposition (Paper 33), and Patent Owner filed a Reply (Paper 37). Patent Owner also filed a Motion for Observation (Paper 27) to which Petitioner filed a Response (Paper 34).

We held a consolidated hearing on August 3, 2017, for this case and related Case IPR2016-01021, and a transcript of the hearing is included in the record. Paper 39 ("Tr.").

B. Related Proceedings

The parties indicate that the '243 patent is the subject of several district court cases. Pet. 1; Paper 5, 2–3; Paper 10.

C. The '243 patent (Ex. 1001)

The '243 patent discloses multicarrier communication systems that lower the peak-to-average power ratio (PAR) of transmitted signals. Ex. 1001, 1:26–29. A value is associated with each carrier signal, and a phase shift is computed for each carrier signal based on the value associated with that carrier signal. *Id.* at 2:36–40. The computed phase shift value is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals. *Id.* at 2:40–43.

Figure 1 illustrates the multicarrier communication system and is reproduced below:

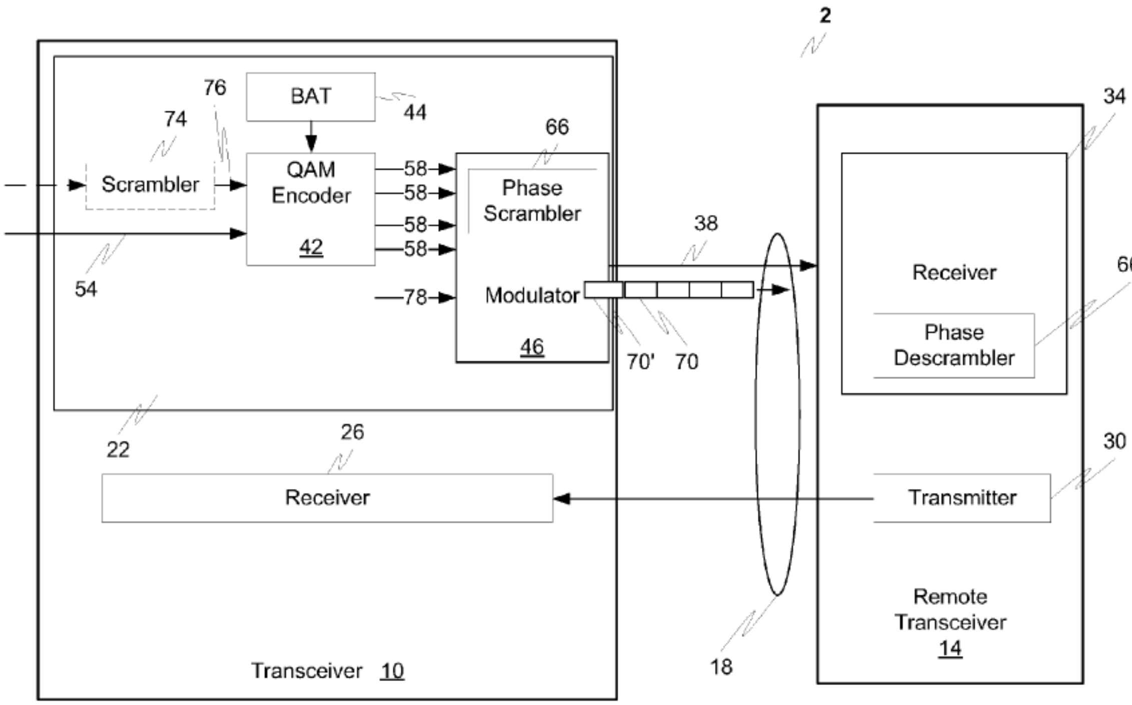


FIG. 1

Figure 1 illustrates the multicarrier communication system, digital subscriber line (DSL) communication system 2 includes discrete multitone (DMT) transceiver 10 communicating with remote transceiver 14 over communication channel 18 using transmission signal 38 having a plurality of carrier signals. *Id.* at 3:25–29. DMT transceiver 10 includes DMT transmitter 22 and DMT receiver 26. *Id.* at 3:29–30. Remote transceiver also includes transmitter 30 and receiver 34. *Id.* at 3:30–32. DMT transmitter 22 transmits signals over communication channel 18 to receiver 34. *Id.* at 3:38–41.

DMT transmitter 22 includes quadrature amplitude modulation (QAM) encoder 42, modulator 46, bit allocation table (BAT) 44, and phase scrambler 66. QAM encoder 42 has a single input for receiving serial data bit stream 54 and multiple parallel outputs to transmit QAM symbols 58

generated by QAM encoder 42 from bit stream 54. Modulator 46 provides DMT modulation functionality and transforms QAM symbols 58 into DMT symbols 70. *Id.* at 4:10–13. Modulator 46 modulates each carrier signal with a different QAM symbol 58, and, therefore, this modulation results in carrier signals having phase and amplitude characteristics based on QAM symbol 58. *Id.* at 4:13–16. Modulator 46 also includes phase scrambler 66 that combines a phase shift computed for each QAM-modulated carrier signal with the phase characteristics of that carrier signal. *Id.* at 4:29–32.

D. Illustrative Claims

Petitioner challenges claims 1–25 of the ’243 patent. Pet. 8–52. Claims 1, 7, 13, and 20 are independent claims. Claims 2–6 depend from independent claim 1, claims 8–12 depend from independent claim 7, claims 14–19 depend directly or indirectly from independent claim 13, and claims 21–25 depend from independent claim 20. Claim 1 is illustrative of the claims at issue and is reproduced below:

> 1. A method, in a multicarrier communications transceiver comprising a bit scrambler followed by a phase scrambler, comprising:
>
> scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits, wherein at least one scrambled output bit is different than a corresponding input bit;
>
> scrambling, using the phase scrambler, a plurality of carrier phases associated with the plurality of scrambled output bits;
>
> transmitting at least one scrambled output bit on a first carrier; and
>
> transmitting the at least one scrambled output bit on a second carrier.

Ex. 1001, 10:58–11:4.

II. ANALYSIS

A. Claim Construction

The Board interprets claims of an unexpired patent using the broadest reasonable construction in light of the specification of the patent in which they appear. *See* 37 C.F.R. § 42.100(b); *see Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2142–46 (2016). Under the broadest reasonable construction standard, claim terms are given their ordinary and customary meaning, as would be understood by one of ordinary skill in the art in the context of the entire disclosure. *In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007).

1. "transceiver"

In our Decision on Institution, we construed "transceiver" to mean "a device, such as a modem, with a transmitter and a receiver." Inst. Dec. 6. Patent Owner contends that a construction is not necessary and cites a construction from a corresponding district court matter (Ex. 2007, 8), but does not argue we should adopt this construction. PO Resp. 13–14 ("Petitioners' arguments fail irrespective of which of the foregoing constructions for 'transceiver' is used."). Petitioner contends we should maintain our construction. Reply 7–8. Based on the record developed during this proceeding, we continue to apply this construction.

2. "scrambling . . . a plurality of carrier phases"

Independent claim 1 recites "scrambling . . . a plurality of carrier phases." Independent claim 7 similarly recites "scramble a plurality of carrier phases." Independent claims 13 and 20 similarly recite "scramble[s] a plurality of phases." Patent Owner argues that this language should be interpreted to mean "adjusting the phases of a plurality of carriers in a single

multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14–19. Petitioner argues that the phrase does not need to be interpreted, since the prior art relied upon uses the same "phase scrambling" terminology to describe pseudo-random phase changes. Reply 7 (citing Ex. 1012, 12:24–31). Additionally, Petitioner argues, without any other explanation, that "the Board should not adopt TQ Delta's proposed construction." *Id*. During oral argument, however, counsel for Petitioner reiterated that it is Petitioner's position that no construction of the term is necessary, because "[r]egarding patent owner's proposal of the construction, we believe that is exactly how Stopler is describing his phase scrambler as operating." Tr. 18:23–19:5.

Patent Owner argues that "scramble[e/ing . . . a plurality of carrier phases" and "scramble[] a plurality of phases" should be construed to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol by pseudo-randomly varying amounts." PO Resp. 14. Patent Owner contends that the construction is supported by the Specification of the '243 patent and clarifies that the claimed phase scrambling "must be performed amongst the individual carrier phases in a single multicarrier symbol" and is not met if the phase adjustment only occurs over time from one symbol to the next. PO Resp. 14 (citing Ex. 2003 ¶ 37).

In support of its proposed interpretation, Patent Owner argues that the '243 patent describes that each of the plurality of carriers (of a multicarrier signal) corresponds to a different QAM symbol. PO Resp. 15 (citing Ex. 1001, 4:13–14). Patent Owner further argues that each carrier (or QAM symbol) has its own phase or phase characteristic, and that the combination of the carriers (or QAM symbols) is referred to as a DMT symbol. PO Resp. 16 (citing Ex. 1001, 4:7–9, 9:8–9; Ex. 2003 ¶ 39). Patent Owner further

contends that the ’243 patent describes that a “phase scrambler” scrambles phases or phase characteristics of carriers within a single DMT symbol, and that PAR in the transmission signal is reduced by adjusting the carrier phases within a single DMT symbol. PO Resp. 16 (citing Ex. 1001, 6:30–8:13; Ex. 2003 ¶ 39). PAR, Patent Owner contends, would not be reduced if carrier phases were only adjusted from one symbol to the next. PO Resp. 16 (Ex. 2003 ¶¶ 41–42).

Based on the record before us, we agree with Patent Owner’s proposed construction as far as meaning “adjusting the phases of a plurality of carriers in a single multicarrier symbol.” Patent Owner, however, provides no persuasive reasoning for also adding to that construction “by pseudo-randomly varying amounts.” Rather, Patent Owner merely contends that (1) in a corresponding district court matter, the court construed the phrase to mean “adjusting the phase characteristics of the carrier signals by pseudo-randomly varying amounts;” (2) during prosecution of the ’243 patent, the applicant explained that a “scrambler” operates by pseudo-randomly selecting bits to invert; and (3) there was no fundamental disagreement between parties that scrambling involves adjusting the phase characteristic of a carrier signal by pseudo-randomly varying amounts. PO Resp. 16–17 (citing Ex. 2007, 10–11; Ex. 2008, 18). Patent Owner’s explanation for why we should add “by pseudo-randomly varying amounts” to its proposed construction is conclusory. We interpret claims using the broadest reasonable construction in light of the specification of the involved patent. That standard is not the same as the standard used in district court. Patent Owner, however, provides no explanation for why we should apply the district court construction, which is not necessarily the same as used

before us, here. Moreover, the statement made during prosecution is in the context of summarizing an interview, purports to be part of a definition from Wikipedia, and is preceded by an "e.g." (Ex. 2008, 18). Patent Owner does not explain persuasively why this statement should be interpreted as disclaiming other possible forms of scrambling. In summary, Patent Owner's arguments are conclusory.

For all of the above reasons, and for purposes of this decision, we determine that "scrambling the phase characteristics of the carrier signals" means "adjusting the phases of a plurality of carriers in a single multicarrier symbol."

B. Level of Ordinary Skill in the Art

Petitioner contends that a hypothetical person of ordinary skill in the art, with respect to and at the time of the'243 patent, would have, "(i) a Master's degree in Electrical and/or Computer Engineering, or equivalent training, and (ii) approximately five years of experience working in multicarrier telecommunications," and that a "[l]ack of work experience can be remedied by additional education, and vice versa." Pet. 9–10. Patent Owner's expert, Dr. Short, agrees. Ex. 2003 ¶ 16 ("For purposes of this declaration only, I have adopted Dr. Tellado's definition of a person of ordinary skill in the art.")

We determine that the hypothetical person of ordinary skill in the art would have had either Master's degree in Electrical and/or Computer Engineering, or equivalent training, and approximately five years of experience working in multicarrier telecommunications. We note also that the prior art itself often reflects an appropriate skill level. *Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001) ("[T]he level of skill in the

art is a prism or lens through which a judge, jury, or the Board views the prior art and the claimed invention."); *Ryko Mfg. Co. v. Nu-Star, Inc.*, 950 F.2d 714, 718 (Fed. Cir. 1991) ("The importance of resolving the level of ordinary skill in the art lies in the necessity of maintaining objectivity in the obviousness inquiry.").

C. The Parties' Post-Institution Arguments

In our Decision on Institution, we concluded that the arguments and evidence advanced by Petitioner demonstrated a reasonable likelihood that claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively and Stopler, and that claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and Gerszberg. Inst. Dec. 16. We must now determine whether Petitioner has established by a preponderance of the evidence that the specified claims are unpatentable over the cited prior art. 35 U.S.C. § 316(e). We previously instructed Patent Owner that "any arguments for patentability not raised in the [Patent Owner Response] will be deemed waived." Paper 8, 6; *see also* 37 C.F.R. § 42.23(a) ("Any material fact not specifically denied may be considered admitted."); *In re Nuvasive, Inc.*, 842 F.3d 1376, 1379–1382 (Fed. Cir. 2016) (holding Patent Owner waived argument addressed in Preliminary Response by not raising argument in the Patent Owner Response). Additionally, the Board's Trial Practice Guide states that the Patent Owner Response "should identify all the involved claims that are believed to be patentable and state the basis for that belief." Office Patent Trial Practice Guide, 77 Fed. Reg. 48,756, 48,766 (Aug. 14, 2012).

With a complete record before us, we note that we have reviewed arguments and evidence advanced by Petitioner to support its unpatentability contentions where Patent Owner chose not to address certain limitations in its Patent Owner Response. In this regard, the record now contains persuasive, unrebutted arguments and evidence presented by Petitioner regarding the manner in which the asserted prior art teaches corresponding limitations of the claims against which that prior art is asserted. Based on the preponderance of the evidence before us, we conclude that the prior art identified by Petitioner teaches or suggests all uncontested limitations of the reviewed claims. The limitations that Patent Owner contests in the Patent Owner Response are addressed below.

D. Obviousness of Claims 1–3, 7–9, 13–16, and 20–22 over Shively and Stopler

Petitioner contends that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler. Pet. 10–42.

1. Principles of Law

A claim is unpatentable under § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations, including (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of skill in the art; and (4) when in evidence, objective indicia of non-obviousness

(i.e., secondary considerations). *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). We analyze this asserted ground based on obviousness with the principles identified above in mind.

2. Shively Overview

Shively discloses discrete multitone transmission (DMT) of data by digital subscriber loop (DSL) modems and the allocation of bits to the discrete multitones. Ex. 1011, 1:5–8. Bit allocation is performed to optimize throughput within aggregate power and power spectral density mask limits. *Id.* at 4:17–19. The system includes a transmitting modem and a receiving modem connected by a cable having four twisted pairs of conductors. *Id.* at 9:63–65. The modems include a source encoder, a channel decoder, and a digital modulator to take in and transmit data from a data source. *Id.* at 10:9–12. The modems also include a digital demodulator, a channel decoder, and a source decoder to receive the data and supply it to a data sink. *Id.* at 10:12–14. The source encoder compresses data, applies the compressed data to the channel decoder, which performs error correction. *Id.* at 10:15–19. The error corrected data is applied to the digital modulator, which acts as the interface with the communication channel. *Id.* at 10:15–22. The digital demodulator constructs a data stream from the modulated signal and applies it to the channel decoder, which performs error correction, and then applies the corrected data to the source decoder, which decompresses the data. *Id.* at 10:22–26.

In the QAM multitone modulation, the spectrum is broken into multiple sub-bands or QAM channels. *Id.* at 10:27–29. The digital modulator generates N QAM signal tones, one for each QAM channel. *Id.*

at 10:29–30. The serial stream is segmented into N frames, each having allocated to it k_i bits of data. *Id.* at 10:30–31. The multi-carrier modulator generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. *Id.* at 10:35–37.

3. Stopler Overview

Stopler discloses a method and apparatus for encoding/framing a data stream of multitone modulated signals to improve impulse burst immunity. Ex. 1012, 1:8–11. The encoding/framing scheme allows efficient operation in multipoint to point channels affected by ingress and impulsive interference. *Id.* at 5:11–14. Two dimensional interleaving is performed, with one dimension being time and the other dimension being frequency (tones or sub-channels). *Id.* at 5:18–20. Stopler further discloses a diagonalization scheme, where data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. *Id.* at 5:64–67.

4. Petitioner's Initial Positions

Petitioner contends that a combination of Shively and Stopler would have rendered obvious claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent. Pet. 10–42. We have reviewed the Petition, Patent Owner's Response, and Petitioner's Reply, as well as the relevant evidence discussed in those papers and other record papers, and are persuaded that the record sufficiently establishes Petitioner's contentions for claims 1–3, 7–9, 13–16, and 20–22, and we adopt Petitioner's contentions discussed below as our own.

For example, the claim 1 preamble recites "[a] method, in a multicarrier communications transceiver comprising a bit scrambler

followed by a phase scrambler." Petitioner argues that the combination of Shively and Stopler disclose the preamble. Pet. 15–19. Petitioner argues that Shively discloses a "method for transmission in a multitone communication system," and Shively teaches the use of modems to transmit and receive communications. *Id.* at 15–16 (quoting Ex. 1011, 3:28–29; citing 9:42, 9:63–64, Fig. 2). Petitioner argues that Stopler discloses that "[m]ultitone modulation is a signal transmission scheme which uses a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel" and "[o]ne type of multitone transmission scheme is discrete multitone." *Id.* at 16–17 (quoting Ex. 1012, 1:42–49, 1:50–58; citing Ex. 1009, 31–32) (emphasis omitted). Petitioner further argues that Stopler discloses a transmitter that includes two scramblers, a bit scrambler and a phase scrambler. *Id.* at 18 (citing Ex. 1012, 9:34–37, Fig. 5; Ex. 1009, 33–34). We are persuaded by Petitioner's showing and find that Stopler's scrambler 56 is a bit scrambler and Stopler's QAM mapper and phase scrambler 82 is a phase scrambler.

Claim 1 further recites "scrambling, using the bit scrambler, a plurality of input bits to generate a plurality of scrambled output bits." Petitioner argues that Stopler discloses that "data output by the interleaver 54 is rearranged into a serial bit stream (MSB first) and then scrambled in scrambler 56, which is used to randomize the coded and interleaved data." *Id.* at 19 (quoting Ex. 1012, 9:34–48) (emphasis omitted). Petitioner argues that a person with ordinary skill in the art would have recognized that "Stopler's generating a randomizing sequence that is XORed with an input bit stream constitutes 'scrambling . . . a plurality of input bits.'" *Id.* (citing Ex. 1009, 35). We are persuaded by Petitioner's showing and find that

Stopler's scrambler 56 scrambles a plurality of input bits to generate a plurality of scrambled output bits.

Claim 1 also recites "wherein at least one scrambled output bit is different than a corresponding input bit." Petitioner argues that Stopler discloses that "the bits of the serial bit stream are 'scrambled in scrambler 56' to 'randomize' the data." *Id.* at 20 (citing Ex. 1012, 9:34–47). Petitioner argues that a person with ordinary skill would have recognized that "the XOR operation would result in at least one input bit to be changed when the corresponding bit in the randomizing sequence has a value of 1." *Id.* at 21 (citing Ex. 1009, 37). We are persuaded by Petitioner's showing and find that a person of ordinary skill in the art would have understood that, after Stopler's XOR operation, at least one scrambled output bit is different than a corresponding input bit.

Claim 1 additionally recites "scrambling, using the phase scrambler, a plurality of carrier phases." Petitioner argues that Stopler discloses that "the phase scrambler applies 'a phase scrambling sequence' to 'data in the form of m-tuples which are to be mapped into QAM symbols.'" *Id.* at 21 (quoting Ex. 1012, 12:20–28). Petitioner argues that Stopler discloses that "the phase scrambled symbols are provided to a modulator that performs signal modulation." *Id.* at 21–22 (citing Ex. 1012, 12:55–57, Fig. 5; Ex. 1009, 39–40). Petitioner further argues that both Shively and Stopler disclose "transmitting information by modulating multiple carrier frequencies." *Id.* at 22 (citing Ex. 1011, 8:3–13; Ex. 1012, 1:42–49, 1:50–61; Ex. 1009, 40). Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing and find

that Stopler's QAM mapper and phase scrambler 82 scrambles a plurality of carrier phases.

Claim 1 further recites "a plurality of carrier phases associated with the plurality of scrambled output bits." Petitioner argues that the combination of Shively and Stopler discloses that "the plurality of carrier phases are based on the symbols provided to the modulator" and Stopler further discloses "the symbols are mapped from m-tuple data . . . [where] the m-tuple data provided to QAM mapper and phase scrambler 82 are formed by processing the data output by the big scrambler 56 on an 'upper level' and a 'lower level.'" *Id.* at 23 (citing Ex. 1012, 9:48–55, 10:1–7, 10:40–11:50, 11:51–54, 12:20–22, Fig. 5; Ex. 1009, 42–43). We are persuaded by Petitioner's showing and find that the plurality of scrambled output bits are processed to become m-tuple data that is then "associated with" a plurality of carrier phases by QAM mapper and phase scrambler 82.

Claim 1 also recites "transmitting at least one scrambled output bit on a first carrier" and "transmitting the at least one scrambled output bit on a second carrier." Petitioner argues that Shively discloses determining "a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel" and "modulating a first set of respective carriers to represent respective unique portions of the data stream in at least a subset of those of the multitone subchannels." *Id.* at 24–25 (quoting Ex. 1011, 8:3–6, 8:5–13). Petitioner further argues that Stopler discloses "transmitting data bits by modulating the data bits on carriers using quadrature amplitude modulation (QAM) and multitone (multicarrier) modulation." *Id.* at 25 (citing Ex. 1012, 1:42–49, 12:20–28). Petitioner explains that it would have been obvious to a person with ordinary skill in

the art "to employ the techniques of Shively and Stopler to transmit at least one scrambled output bit that is provided to the modulator." *Id.* (citing Ex. 1009, 49). Petitioner further argues that Shively discloses transmitting a portion of data on multiple carriers, and, therefore, meets the "second carrier" claim limitation. *Id.* at 26–27. We are persuaded by Petitioner's showing and find that both Shively and Stopler teach transmitting at least one scrambled output data bit on a first carrier by modulating it using QAM.

Petitioner argues that "[i]t would have been obvious for a POSITA to combine Shively and Stopler because the combination is merely a use of a known technique to improve a similar device, method or product in the same way." *Id.* at 13 (citing Ex. 1009, 26). Petitioner explains that a person of ordinary skill in the art would have recognized that "by transmitting redundant data on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio" because "the overall transmitted signal in a multicarrier system is essentially the sum of its multiple carriers." *Id.* (citing Ex. 1009, 26). Petitioner asserts that a person of ordinary skill in the art "would have sought out an approach to reduce the [(peak-to-average power ratio)] PAR of Shively's transmitter" and "Stopler provides a solution for reducing the PAR of a multicarrier transmitter." *Id.* at 14 (citing Ex. 1009, 27). Petitioner argues that Stopler discloses "a phase scrambler [that] can be employed to randomize the phase of the individual subcarriers" (*id.* at 14 (quoting Ex. 1011, 12:24–28)) and "[a] POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two subcarriers in Shively's system to transmit the same bits, but without those two subcarriers having the same phase." *Id.* at 14. Petitioner explains that "[s]ince the two subcarriers are

out-of-phase with one another, the subcarriers will not add up coherently at the same time," thereby reducing the peak-to-average power ratio (PAR) in Shively's system. *Id.* at 14–15. Accordingly, Petitioner argues that "[c]ombining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR." *Id.* at 15 (citing Ex. 1009, 28). Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing and find that Petitioner's articulated reasoning has sufficient rational underpinning to support the legal conclusion of obviousness. *See KSR Int'l Co.*, 550 U.S. at 418 (citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006)).

Petitioner performs a similar analysis for claims 2, 3, 7–9, 13–16, and 20–22. Pet. 28–42. Notwithstanding Patent Owner's arguments, which we have considered and which we address below, we are persuaded by Petitioner's showing, which we adopt as our own findings and conclusions, that claims 1–3, 7–9, 13–16, and 20–22 are unpatentable as obvious over Shively and Stopler.

5. Patent Owner's Argument that Stopler Does Not Phase Scramble

Patent Owner contends that "Stopler must be compatible with single-carrier CDMA" (PO Resp. 59) based on Stopler's teaching that "[t]he framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 'Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System.'" Ex. 1012, 12:58–63; PO Resp. 29–30; *see also*

id. at 29–44 (arguing Stopler's framing scheme must be compatible with single-carrier CDMA). According to Patent Owner, "[b]ecause Stopler must be compatible with single-carrier CDMA, it makes no sense to argue that his phase scrambling must be performed within a single multicarrier symbol." PO Resp. 59. Thus, concludes Patent Owner, "Stopler only discloses scrambling phases from one symbol[6] to the next symbol in time, and not with respect to multiple carriers in a single multicarrier symbol." PO Resp. 58–59; *see also id.* at 37 ("[i]t is nonsensical to scramble phases within a symbol because there is only one phase in each symbol.").

Patent Owner also relies on Stopler's claim 31 as corroboration for its position, contending that the phase scrambling performed by QAM Mapper and Phase Scrambler 82 "must at least be compatible with single carrier CDMA" because claim 31 is directed to a method in a "CDMA system" that includes the step of "phase scrambling." *Id*. at 33–34 (citing Ex. 1012, 16:4–48).

The "framing scheme" of Stopler is shown as a block diagram in Figure 5, reproduced below. Ex. 1012, 8:54–55 ("A block diagram of the framing scheme according to the present invention is shown in FIG. 5.").

[6] Patent Owner uses "symbol" to mean "a collective multicarrier symbol in a single symbol period (*e.g*. a DMT symbol)." PO Resp. 12. Patent Owner uses "carrier" to mean "a carrier symbol (*e.g*., a QAM symbol)." *Id.*

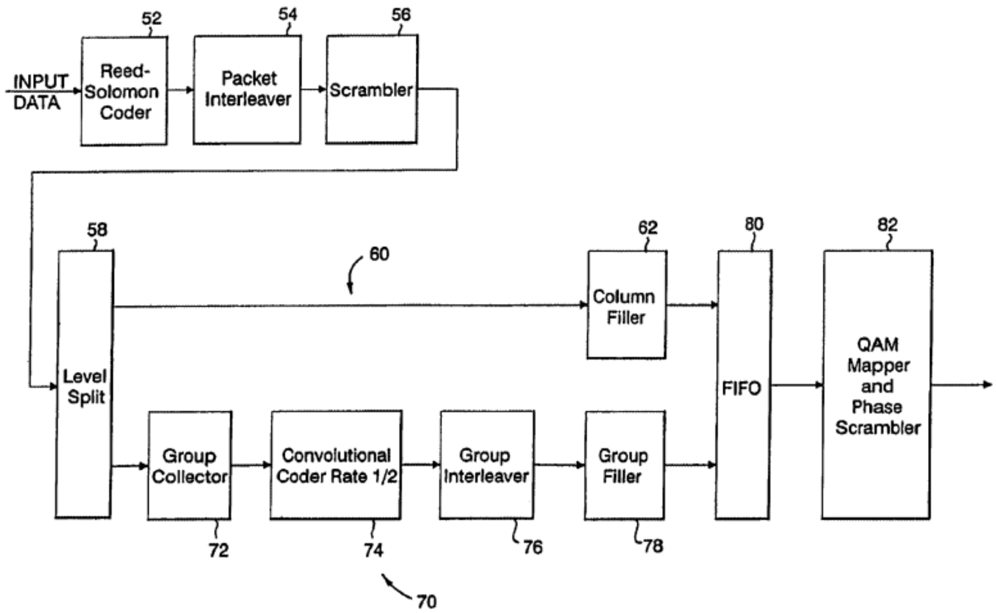
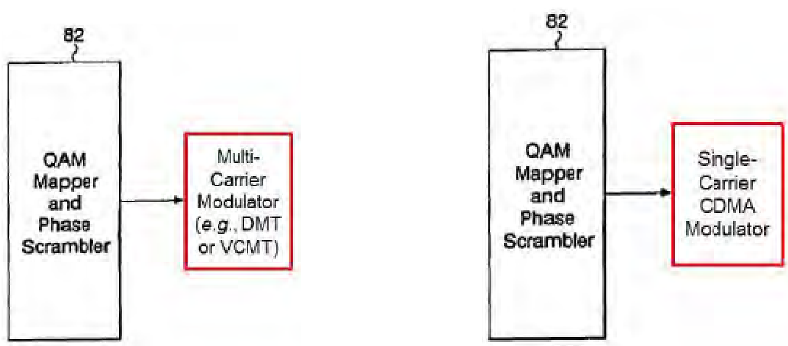


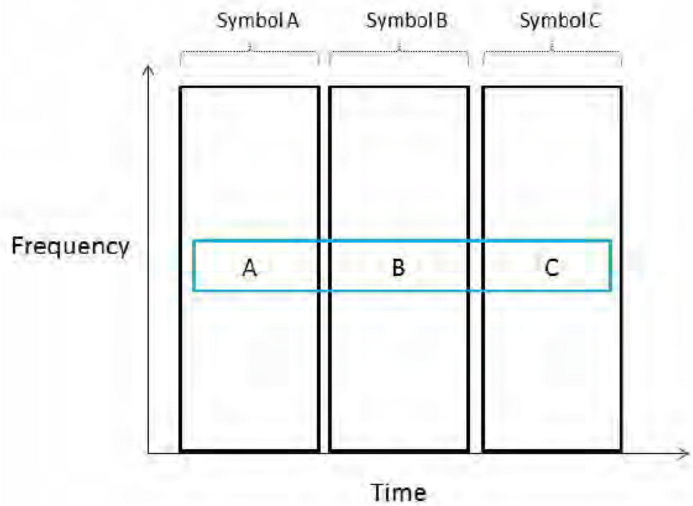
FIG. 5

To illustrate the use of Stopler's framing scheme with either a multicarrier modulator or a single carrier modulator, Patent Owner provides the following annotated excerpts of Figure 5:



PO Resp. 33.

We are not persuaded by Patent Owner's argument, which is based upon its assertion that "[s]ingle-carrier systems have only one carrier with only one phase" and, therefore, "[p]hase scrambling in a single-carrier system only makes sense when it is performed over time from symbol-to-symbol, as illustrated by the blue box," in the figure reproduced below. PO Resp. 36–37.



Id. at 37. In this diagram, "Symbol A," "Symbol B," and "Symbol C" each represent a QAM symbol, not a DMT symbol, and each, according to Patent Owner, is phase scrambled relative to the other. Thus, Patent Owner's diagram shows only that a single-carrier embodiment of Stopler would transmit one phase-scrambled QAM symbol at a time. It does *not* show that QAM Mapper and Phase Scrambler 82 phase scrambles a DMT symbol—i.e., rotates, by the same amount, the phase of a plurality of QAM symbols. This is consistent with the cross-examination testimony of Patent Owner's expert, Dr. Short, who admitted that Stopler does not describe phase scrambling DMT symbols. Reply 17–18 (citing Ex. 1027, 60:11–14). Thus, Patent Owner's own diagram is consistent with Petitioner's position that Stopler phase scrambles individual QAM symbols, and Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol.

Whereas Patent Owner's position relies upon inference, Petitioner's position is supported by express disclosure in Stopler, which unambiguously

teaches "QAM symbols, for example, . . . 256-QAM" whose "constellation mapping may be the same as that used in ADSL." Ex. 1012, 12:20–24. Stopler further teaches that, "a phase scrambling sequence is applied to the output symbols," including "all symbols, not just the overhead symbols." *Id.* at 12:25–28. Patent Owner's expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a "scrambling sequence may be generated by a pseudo-random generator" that generates pairs whose sum "is used to select the amount of rotation to be applied to the symbol," singular; not "symbols" plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner's contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a *single* QAM symbol by that amount. Patent Owner, in contrast, identifies nothing in Stopler to suggest that QAM Mapper and Phase Scrambler 82 rotates the phase of a *plurality* of QAM symbols (e.g., every QAM symbol of a DMT symbol) by the same amount. Finally, we agree with Petitioner's argument that because "a CDMA modulator does not employ DMT symbols, . . . there is no reason for Stopler's phase scrambler to operate on DMT symbols," whereas "both DMT and CDMA modulators employ QAM symbols," so "applying the phase scrambler to individual QAM symbols [] is the only possible reading that is logically and technically coherent." *Id.* at 18–19 (citing Ex. 1026 (Tellado Reply Decl.) ¶ 58).

Patent Owner also argues that a person of ordinary skill in the art would have understood Stopler to be scrambling phase from symbol-to-symbol over time in order to reduce narrowband noise at the frequency of an

overhead pilot carrier. PO Resp. 39; *see also id.* at 38–44 (citing Ex. 2004 (U.S. Patent 6,370,156, "the '156 patent")). According to Patent Owner, "Petitioners' argument that Stopler discloses phase scrambling within one symbol is based on the premise that the symbol can have multiple pilot tones." *Id.* at 40. We understand Patent Owner to be alluding to pages 12 to 13 of the Petition, which state

> Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals, such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26.

Pet. 12–13. In the claim-by-claim analysis of the Petition, however, Petitioner cites lines 20 to 28 of column 12, which include Stopler's teaching that "the phase scrambler is applied to all symbols, not just the overhead symbols." Pet. 21 (quoting Ex. 1012, 12:27–28). Thus, Petitioner is relying not just on the scrambling of "overhead signals, such as pilot tones," (Pet. 12) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive.

Finally, we are not persuaded by Patent Owner's argument that only its interpretation—i.e., adjusting the phase of an entire DMT symbol—would "simplify implementation," as Stopler teaches (Ex. 1012, 12:26), whereas Petitioner's interpretation would add complexity. PO Resp. 44 (citing Ex. 2003 ¶ 90). Patent Owner provides no explanation or analysis to support its conclusory assertions regarding simplicity and complexity, and the cited portion of Dr. Short's declaration merely repeats what is written in the Patent Owner's Response.

For the foregoing reasons, we are persuaded that Stopler teaches "scrambling, using the phase scrambler, a plurality of carrier phases," as recited in independent claim 1 and similarly recited in independent claims 7, 13, and 20.

6. Patent Owner's Assertions Concerning Reason to Combine

Patent Owner argues that the combined teachings of Shively and Stopler do not render obvious the challenged claims. PO Resp. 44. In particular, Patent Owner argues that (1) Petitioner provides no explanation for the "use of a known technique to improve a similar device" rationale to combine Shively and Stopler (*id*. at 45–47); (2) Petitioner wrongly claims that Shively's transmitter suffers from an increased PAR (*id*. at 47–49); (3) Petitioner's combination of Shively and Stopler suffers from hindsight (*id*. at 49–50); (4) there is no need to solve Shively's non-existent PAR problem (*id*. at 50); (5) Stopler does not reduce PAR in a multicarrier transmitter (*id*. at 51); (6) Stopler and Shively could not be combined (*id*. at 51–55); and (7) there were no "market forces" in effect to prompt Shively/Stopler combination (*id*. at 55–57). We address each argument in turn.[7]

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[7] Patent Owner lists several portions of Petitioner's Reply and evidence allegedly beyond the scope of what can be considered appropriate for a reply. *See* Paper 22. We have considered Patent Owner's listing, but disagree that the cited portions of Petitioner's Reply and reply evidence are beyond the scope of what is appropriate for a reply. Replies are a vehicle for responding to arguments raised in a corresponding patent owner response. Petitioner's arguments and evidence that Patent Owner objects to (Paper 22, 1–2) are not beyond the proper scope of a reply because we find that they fairly respond to Patent Owner's arguments raised in Patent Owner's Response. *See Idemitsu Kosan Co. v. SFC Co. Ltd.*, 870 F.3d 1376, 1381

a. Use of a known technique to improve a similar device rationale

Patent Owner argues that in making the contention that the combination of Shively and Stopler is a use of a known technique to improve a similar device, method or product in the same way, Petitioner fails to explain what is the known technique, what device/method/product is similar, and how is the alleged known technique used for improvement in the same way. PO Resp. 45–47.

In the Petition, Petitioner provides sufficient explanation regarding the reasons to combine Shively and Stopler. Pet. 13–15. The explanation provided in the Petition is not conclusory or confusing as Patent Owner asserts. The known technique is identified as phase scrambling. Pet. 14–15 (citing Ex. 1009, 27–28). The similar device is Shively's modem. Pet. 16. And the improvement to it is the same as in Stopler—to reduce PAR. Pet. 15 (citing Ex. 1009, 28–29).

b. Whether Shively's transmitter suffers from increased PAR and whether there is a reason to reduce PAR in Shively

Patent Owner argues that "Shively does not suffer from an increased PAR, much less one that would be recognized as a problem. Rather, Shively's disclosed embodiment results in a substantially reduced PAR (and one that is very far below a level that is problematic)." PO Resp. 47–49.

(Fed. Cir. 2017) ("This back-and-forth shows that what Idemitsu characterizes as an argument raised 'too late' is simply the by-product of one party necessarily getting the last word. If anything, Idemitsu is the party that first raised this issue, by arguing—at least implicitly—that Arakane teaches away from non-energy-gap combinations. SFC simply countered, as it was entitled to do.").

Patent Owner also argues that because Shively does not disclose a problem with PAR, one having ordinary skill in the art would have had no reason to look for a solution. PO Resp. 50. We are not persuaded by these arguments.

Specifically, Patent Owner argues Shively's system is unlikely to suffer from clipping[8] based on its analysis of a hypothetical 18,000 foot wire. PO Resp. 19–28. According to Patent Owner, the power of signals transmitted in Shively's proposed system would be "only 40% of maximum" in the normal mode for ADSL-1995 and "only 49% of maximum" in the power-boost mode of ADSL-1995. PO Resp. 19–28. Based on these figures, Patent Owner concludes that "the clipping probability for both normal and power-boost modes is virtually zero" because "[w]hile Shively's 'spreading' technique will contribute a small uptick in clipping probability, any increase would be negated by the enormous reduction in clipping probability achieved by reducing signal power by more than half." *Id.* at 28.

Petitioner argues that Dr. Short's analysis is flawed because (1) the teachings of Shively are not applicable only to 18,000 foot cables; and (2) Dr. Short "grossly underestimates the likelihood of phase alignment" in Shively because he wrongly assumes a Gaussian distribution. Reply 26–31. According to Petitioner, a proper analysis shows that Shively's techniques "significantly increases PAR and the likelihood of clipping." Reply 32–36 (emphasis omitted).

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[8] Patent Owner explains that, "[w]hen the maximum dynamic range of a component is exceeded, the signal will become distorted or will 'clip.'" PO Resp. 8. This is consistent with how the '243 patent uses "clipping." *See, e.g.*, Ex. 1001, 8:27–35.

We need not determine the exact probability of clipping in Shively's proposed system because, even assuming Patent Owner's analysis is accurate, it does not rebut Petitioner's reason to combine. Petitioner does not allege that Shively's proposed system causes clipping, or that a person of ordinary skill in the art would have been motivated to reduce PAR only if it caused clipping. Instead, Petitioner alleges that Shively's proposed system would have an "increased" or "high" PAR:

> A POSITA would have recognized that by transmitting redundant data on multiple carriers, *Shively's transmitter would suffer from an increased peak-to-average power ratio*. Ex. 1009, p. 26. This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. *Id*. When N subcarrier signals with the same phase are added together, they have a peak power which is N times greater than their individual maximum powers. *Id*.
>
> Since Shively's subcarriers use quadrature amplitude modulation (QAM) . . . transmitting the same bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. *Id*. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. *Id*. *Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time*. *Id*.

Pet. 13–14 (emphases added).

Patent Owner criticizes Petitioner's declarant for not providing "calculations or data that illustrate to what degree there is an 'increase' in PAR with Shively's transmitter" (PO Resp. 48), but we are not persuaded that such calculations and data are necessary. Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold. There is no dispute that transmitting the same data on multiple

carriers increases PAR (Reply 10 (citing PO Resp. 6–7; Ex. 2003 (Short Decl.) ¶ 22)) or that Shively's technique, specifically, will increase PAR (PO Resp. 28 ("Shively's 'spreading' technique will contribute a small uptick in clipping probability"). There also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR (Reply 37; Ex. 2003 (Short Decl.) ¶ 26; Ex. 1027 (Short Depo.) 45:21–19). Patent Owner's declarant, Dr. Short, testified that, given such issues, system designers or engineers would be interested in using techniques that could reduce PAR. Ex. 1027, 46:23–47:3. This is consistent with the reason to combine given in the Petition and supports Petitioner's position that "numerous problems" other than clipping "would have motivated a [person of ordinary skill in the art] to look for ways to reduce the PAR of Shively's technique." Reply 37.

In light of the foregoing, we are persuaded that a person of ordinary skill in the art would have recognized that Shively's technique would increase PAR and would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping.

c. Whether combination of Shively and Stopler suffers from hindsight

Patent Owner argues that only the inventor of the '243 patent recognized the problem of high PAR due to phase-aligned carriers. PO Resp. 49–50. Patent Owner argues that the only cited evidence that high PAR results from transmitting the same data on multiple carriers is from the '243 patent and that Petitioner "use[s] the '243 patent as a roadmap for arriving at their theory of obviousness" and "is a textbook case of impermissible hindsight bias." *Id*. We are not persuaded by this argument.

First, the portions cited in the ’243 patent in the Petition and in Dr. Tellado’s declaration come from the “BACKGROUND OF THE INVENTION” section of the patent. That portion of the ’243 patent uses words such as “conventional” indicating that what is described in the “BACKGROUND OF THE INVENTION” section is information that was known at the time of the invention, not just by the inventors, but persons of ordinary skill in the art. Patent Owner does not contend otherwise.

In addition, Dr. Tellado testified that a person having ordinary skill in the art would have recognized that the purpose of Stopler’s phase scrambler to randomize data symbols would be to reduce PAR of transmitted signals and that the person would have been familiar with the problems created by a high PAR, including PAR due to phase-aligned carriers. Ex. 1009 ¶¶ 60, 66. Moreover, Patent Owner’s own declarant recognized that PAR was a known problem at the time of the invention. Ex. 2003 ¶ 23 (“Conventional multicarrier systems, therefore, were designed to accommodate PAR.”). The ANSI T1.413-1995 standard also confirms that PAR was known at the time of the invention by describing that “[a] DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analog converter.” Ex. 1017, 36 (Section 6.5 “Tone ordering”). Based on the record evidence, we find that a person having ordinary skill in the art would have known about the problem of high PAR due to phase-aligned carriers.

d. Whether Stopler reduces PAR in a multicarrier transmitter

Patent Owner argues that Stopler does not reduce PAR because phase scrambling is performed from symbol-to-symbol and not from carrier-to-

carrier. PO Resp. 51. The argument is not persuasive for the reasons provided above.

e. Whether Stopler and Shively could be combined

Patent Owner argues that Shively and Stopler are incompatible and that it would not have been possible to incorporate Shively's bit-spreading concept into Stopler. PO Resp. 51. In particular, Patent Owner argues that Shively's bit-spreading concept is not compatible with Stopler's "diagonalization" technique. PO Resp. 51–55. This argument is misplaced as Petitioner did not rely on Stopler's "diagonalization" technique. Rather, Petitioner relies on Stopler's phase scrambler and scrambling technique. Pet. 14, 21–22. Moreover, Stopler describes its "diagonalization" technique as optional. Ex. 1012, 10:17, 13:1–3. For these reasons, we are not persuaded by Patent Owner's argument that it would not be possible to combine Shively and Stopler.

f. Whether "market forces" prompt Shively/Stopler combination

The Petition states that "[m]arket forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling." Pet. 15 (citing Ex. 1009, 28). Patent Owner argues that neither Petitioner nor Dr. Tellado identifies a single product or standard that employs any of the ideas disclosed in Shively or Stopler. PO Resp. 55–57.

Patent Owner's arguments are misplaced. It was not incumbent on Petitioner or Dr. Tellado to identify a product or standard that employs the

ideas disclosed in Shively or Stopler in order to show that the combination of Shively and Stopler would have been obvious to a person skilled in the art. That is not the standard. Rather, a claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time of the invention to a person having ordinary skill in the art. *KSR Int'l Co.*, 550 U.S. at 406. Dr. Tellado testified that a person having ordinary skill in the art would have been familiar with problems caused by a high PAR, that equipment needed to cope with PAR would have been expensive and inefficient, and that less capable equipment would have caused distortion such as from amplitude clipping. Ex. 1009 ¶ 66. He further testified that combining Shively's redundant bit transmission with Stopler's phase scrambling technique would have allowed for faster DSL modems without requiring more complex and expensive circuitry for handling increased PAR. *Id.* ¶ 69. Patent Owner has not presented sufficient evidence to undermine Dr. Tellado's testimony. Indeed, Dr. Short testified that a way to address high PAR in a communication system would be to use transceiver components that could handle higher peak transmission values, which would be expensive and power hungry. Ex. 1027, 45:15–46:12. Based on the record before us, we find that at the time of the invention, a person having ordinary skill in the art would have recognized that an increase in PAR would have been associated with more expensive communication equipment. Accordingly, a drive to reduce equipment costs would have motivated a person having ordinary skill in the art to include Stopler's phase scrambler into Shively's transmitter to reduce PAR. Pet. 13–15; Ex. 1009 ¶¶ 66–70.

7. Summary

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 1–3, 7–9, 13–16, and 20–22 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively and Stopler.

E. Obviousness of Claims 4–6, 10–12, 17–19, and 23–25 over Shively, Stopler, and Gerszberg

Petitioner contends that claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerszberg. Pet. 42–52.

1. Gerszberg Overview

Gerszberg discloses a telephone network interface unit typically disposed on the outside of a home or small business. Ex. 1013, 1:6–9. An intelligent services director (ISD) is placed near a customer’s premises for multiplexing and coordinating many digital services on to a single twisted-pair line. *Id.* at 2:12–23. A facilities management platform (FMP) is placed in the local telephone network’s central office for routing data to an appropriate interexchange company network. *Id.* A network server platform (NSP) is coupled to the FMP. *Id.*

2. Petitioner’s Initial Contentions

Petitioner contends that a combination of Shively and Stopler would have rendered obvious claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent. Pet. 42–52. We have reviewed the Petition, Patent Owner’s Response, and Petitioner’s Reply, as well as the relevant evidence discussed in those papers and other record papers, and are persuaded that the record sufficiently establishes Petitioner’s contentions for claims 4–6, 10–12, 17–

19, and 23–25, and we adopt Petitioner's contentions discussed below as our own.

For example, the claim 4 recites "[t]he method of claim 1, wherein the transceiver is a wireless transceiver," claim 5 recites "[t]he method of claim 1, wherein the transceiver is operable for high speed internet access," and claim 6 recites "[t]he method of claim 1, wherein the transceiver is operable to transport video." Petitioner argues that, as discussed above, the combination of Shively and Stopler renders claim 1 obvious. *See* Section II.B.3. Petitioner further argues that Gerszberg discloses the additional limitations of claims 4–6. Pet. 47–49. Petitioner explains that Gerszberg discloses a "transceiver [that] is 'coupled to a central office [] via a twisted-pair wire, hybrid fiber interconnection, wireless and/or other customer connection.'" *Id.* at 48 (quoting Ex. 1013, 2:67–3:9) (emphasis omitted). Petitioner also argues that Gerszberg discloses "'[h]igh-speed access to the Internet' and the 'ability to offer ultra fast Internet access.'" *Id.* (quoting Ex. 1013, 7:44–60, 8:16–24). Petitioner additionally argues that Gerszberg discloses "transporting 'video' and providing '[i]nteractive video teleconferencing.'" *Id.*at 49 (quoting Ex. 1013, 8:16–36, 10:63–11:3). We are persuaded by Petitioner's showing and find that Gerszberg teaches a wireless transceiver, a transceiver operable for high speed internet access, and a transceiver operable transport video.

Petitioner further argues that a person with ordinary skill in the art would have combined Gerszberg with Shively/Stopler "because Shively explicitly refers to Gerszberg and incorporates Gerszberg by reference." *Id.* at 43–44 (citing Ex. 1011, 18:7–9; Ex. 1013, 16:52–53; Ex. 1009, 69; *Telemac Cellular Corp. v. Topp Telecom, Inc.*, 247 F.3d 1316, 1329 (Fed.

Cir. 2001) (holding "[w]hen a document is 'incorporated by reference' into a host document, such as a patent, the referenced document becomes effectively part of the host document as if it were explicitly contained therein.")). Petitioner alternatively argues that "it would have been obvious to combine the teachings of Gerszberg with Shively and Stopler because the combination is merely the use of a known technique to improve a similar device, method or product in the same way." *Id.* at 44 (citing Ex. 1009, 69). Petitioner explains that both Shively and Stopler "describe transmitting data using DSL and multitone communication technologies" and a person with ordinary skill in the art would have recognized that DSL "was intended to provide data services such as high-speed internet and video to telephone subscribers." *Id.* (citing Ex. 1011, 1:5–8; Ex. 1012, 1:50–61, 9:37–41, 12:21–24, 12:55–57; Ex. 1009, 69). Petitioner argues that it was known that "Service Systems" that are offered by DSL technologies include "Internet access," "Interactive video," and "Videoconferenc[ing]." *Id.* at 44–45 (citing Ex. 1015, 100, 102, 104, Fig. 1). Accordingly, Petitioner argues, and we agree, that the "known technique for providing Internet and video services, as disclosed by Gerszberg, would be applied to the combination of Shively and Stopler to provide the advantage of addressing the market need for such services." *Id.* at 46 (citing Ex. 1013, 7:44–60, 8:16–36, 10:63–11:3).

Patent Owner argues that "Petitioners' assertion of unpatentability for the dependent claims . . . also falls short" for the same reasons argued above with respect to the independent claims. PO Resp. 59. We have addressed those arguments above, and, for the same reasons discussed above, are not persuaded. *See* Section II.D.5 and II.D.6.

3. Summary

For the foregoing reasons, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 4–6, 10–12, 17–19, and 23–25 of the ’243 patent are unpatentable under 35 U.S.C. § 103(a) as obvious over Shively, Stopler, and Gerzberg.

F. Patent Owner’s Motion to Exclude

Patent Owner filed a Motion to Exclude (Paper 28, “Motion”). Petitioner filed an Opposition to Patent Owner’s Motion (Paper 33, “Opp.”), and Patent Owner filed a Reply in support of its Motion (Paper 37). Patent Owner seeks to exclude Exhibit 1022, Exhibit 1025, certain paragraphs of the Exhibit 1026 (Second Tellado Decl.), and Exhibits 1023, 1024, and 1028 and testimony regarding the same. Mot. 2–12. As movant, Patent Owner has the burden of proof to establish that it is entitled to the requested relief. *See* 37 C.F.R. § 42.20(c). For the reasons stated below, Patent Owner’s Motion to Exclude is *dismissed*.

Exhibit 1022 is styled “Robert T. Short, ‘Physical Layer,’ *in* WIMEDIA UWB (2008),” and Exhibit 1025 is a copy of Dr. Tellado’s thesis. Reply 5. Patent Owner argues that we should exclude Exhibits 1022 and 1025 as irrelevant under Federal Rule of Evidence (“FRE”) 402. Motion 2–6. These exhibits were not cited or discussed in Petitioner’s Reply, and we did not rely on Exhibit 1022 or 1025, or Dr. Tellado’s statements with respect to Exhibits 1022 and 1025, in rendering our decision. We did not and need not consider Exhibits 1022 and 1025. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence or the portion of Dr. Tellado’s statements that discuss

Exhibits 1022 and 1025. Accordingly, we *dismiss* Patent Owner's Motion to Exclude as to these exhibits.

Exhibit 1023 is styled "Denis J. G. Mestdagh and Paul M. P. Spruyt, 'A Method to Reduce the Probability of Clipping in DMT-Based Transceivers," *IEEE Transactions on Communications*, Vol. 44, No. 10, (October 1996)." Reply 5. Exhibit 1024 is styled "Stefan H. Muller and Johannes B. Huber, 'A Comparison of Peak Power Reduction Schemes for OFDM,' IEEE Global Telecommunications Conference (1997)." *Id*. Exhibit 1028 is styled "T. Starr, J. M. Cioffi, P. J. Silverman, UNDERSTANDING DIGITAL SUBSCRIBER LINE TECHNOLOGY (1999) (selected pages)." *Id*. Exhibit 2013 is a copy of the cross examination transcript of Dr. Tellado.

Patent Owner argues that we should exclude Exhibits 1023, 1024, and 1028 in their entirety as irrelevant. Motion 9–12. Patent Owner also argues that we should exclude certain portions of Exhibit 2013 allegedly discussing Exhibits 1023, 124, or 1028. *Id*. Although Exhibits 1023, 1024, and 1028 are mentioned briefly in Petitioner's Reply, we did not rely on Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013 in rendering our decision. We did not and need not consider Exhibits 1023, 1024, 1028, or the objected to portions of Exhibit 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence.

Finally, Patent Owner argues that we should exclude paragraphs 16 (last two sentences), 29, 42, 43 (first sentence), and 52 of Exhibit 1026 (Second Tellado Declaration), and certain portions of Dr. Tellado's cross

examination transcript (Exhibit 2013) under FRE 702 as being based on insufficient facts or data due to an alleged undisclosed simulation. Motion 6–9. We did not rely on the objected to portions of Exhibits 1026 or 2013 in rendering our decision. We did not and need not consider the objected to portions of Exhibits 1026 or 2013. We have determined that Petitioner has demonstrated, by a preponderance of the evidence, that the challenged claims are unpatentable, without considering the specific objected to evidence. Accordingly, we *dismiss* Patent Owner's Motion to Exclude as to these paragraphs of Exhibit 1026 and these portions of Exhibit 2013.

For all of the above reasons, we *dismiss* Patent Owner's Motion to Exclude.

G. Motion for Observations

Patent Owner also filed a Motion for Observations (Paper 27, "Obs."), to which Petitioner filed a Response (Paper 34, "Obs. Resp."). To the extent Patent Owner's Motion for Observations pertains to testimony purportedly impacting Dr. Tellado's credibility, we have considered Patent Owner's observations and Petitioner's responses in rendering this Final Written Decision, and accorded Dr. Tellado's testimony appropriate weight in view of Patent Owner's observations and Petitioner's response to those observations. *See* Obs. 1–13; Obs. Resp. 2–11.

III. CONCLUSION

Petitioner has demonstrated, by a preponderance of the evidence, that (1) claims 1–3, 7–9, 13–16, and 20–22 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively and Stopler; and (2) claims 4–6, 10–12, 17–19, and 23–25 of the '243 patent are unpatentable under 35 U.S.C. § 103(a) over Shively, Stopler, and Gerszberg.

IV. ORDER

Accordingly, it is

ORDERED that claims 1–25 of the ’243 patent are determined to be *unpatentable*;

FURTHER ORDERED that Patent Owner’s Motion to Exclude is *dismissed*; and

FURTHER ORDERED that, because this is a Final Written Decision, parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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Paper No. 43
Entered: February 1, 2018

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CISCO SYSTEMS, INC., DISH NETWORK, LLC,
COMCAST CABLE COMMUNICATIONS, LLC,
COX COMMUNICATIONS, INC.,
TIME WARNER CABLE ENTERPRISES LLC,
VERIZON SERVICES CORP., and ARRIS GROUP, INC.,
Petitioner,

v.

TQ DELTA, LLC,
Patent Owner.

Case IPR2016-01020[1]
Patent 9,014,243 B2

Before SALLY C. MEDLEY, TREVOR M. JEFFERSON, and MATTHEW R. CLEMENTS, *Administrative Patent Judges*.

CLEMENTS, *Administrative Patent Judge*.

DECISION
Request for Rehearing
37 C.F.R. § 42.71

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[1] DISH Network, LLC, who filed IPR2017-00254, and Comcast Cable Communications, LLC, Cox Communications, Inc., Time Warner Cable Enterprises LLC, Verizon Services Corp., and ARRIS Group, Inc., who filed IPR2017-00418, have been joined in this proceeding. Paper 14; Paper 15.

I. INTRODUCTION

Pursuant to 37 C.F.R. § 42.71(d), TQ Delta, LLC (“Patent Owner”) request rehearing of our Final Written Decision (Paper 41, “Dec.”). Paper 42 (“Req. Reh’g”). Specifically, Patent Owner submits that our construction of “scrambling . . . a plurality of carrier phases” misapprehends or overlooks certain evidence, that Stopler[2] does not disclose “scrambling . . . a plurality of carrier phases,” that we misapprehended or overlooked certain testimony, and that we misapprehended that Shively[3] would not have an increased or high PAR. Req. Reh’g *passim*.

For the reasons set forth below, Patent Owner’s Request for Rehearing is *denied*.

II. STANDARD OF REVIEW

A party requesting rehearing bears the burden of showing that the decision should be modified. 37 C.F.R. § 42.71(d). The party must identify specifically all matters we misapprehended or overlooked, and the place where each matter was addressed previously in a motion, an opposition, or a reply. *Id.* With this in mind, we address the arguments presented by Patent Owner.

III. ANALYSIS

A. “scrambling . . . a plurality of carrier phases”

Independent claim 1 recites “scrambling . . . a plurality of carrier phases.” Independent claim 7 similarly recites “scramble a plurality of

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[2] U.S. Patent No. 6,625,219 B1; issued Sept. 23, 2003 (Ex. 1012, “Stopler”).
[3] U.S. Patent No. 6,144,696 B1; issued Nov. 7, 2000 (Ex. 1011, “Shively”).

carrier phases." Independent claims 13 and 20 similarly recite "scramble[s] a plurality of phases." We adopted Patent Owner's proposed construction in part by construing "scrambling . . . a plurality of carrier phases" to mean "adjusting the phases of a plurality of carriers in a single multicarrier symbol." Dec. 6–9. We did not add to that construction "by pseudo-randomly varying amounts" because Patent Owner did not show why that additional language should be included for the broadest reasonable construction of the term "scrambling . . . a plurality of carrier phases." *Id*. Patent Owner argues that our construction is overly broad because it encompasses adjusting the phases of every carrier in the single multicarrier symbol by the same amount. Req. Reh'g. 1–2. Such an adjustment, according to Patent Owner, would not reduce peak-to-average power ratio ("PAR"), which the parties and the panel all agree scrambling must do. *Id.* at 3–5. "The FWD misapprehends or overlooks that, under any proper construction, there must at a minimum be *varying amounts* by which the phases are adjusted within a single multicarrier symbol (*i.e.*, *from carrier-to-carrier*) such that PAR is reduced." *Id.* at 2.

Patent Owner presents arguments not presented previously. We could not have overlooked or misapprehended those arguments presented for the first time in the rehearing request. Importantly, Patent Owner argues now for the first time that for any proper construction "there must at a minimum be varying amounts by which the phases are adjusted within a single multicarrier symbol (i.e., from carrier-to-carrier) such that PAR is reduced." *Id.* at 2. This proposed construction differs from Patent Owner's original proposed construction which included "by pseudo-randomly varying

amounts." Absent from the new proposed construction is the term "pseudo-randomly."

In any event, it is clear from the Decision that we construed the totality of each claim as requiring varying the amount by which the phase of each carrier is adjusted. *See, e.g.*, Dec. 21–24. Accordingly, even if we were to adopt Patent Owner's new proposed construction, it would not change the way we applied the prior art to the claim language as a whole.

B. Stopler's Single-Carrier Embodiment

Patent Owner argues that Stopler's QAM Mapper and Phase Scrambler 82 "must be compatible with single-carrier CDMA" because Stopler teaches that its output can, in one embodiment, be provided to a CDMA modulator. Req. Reh'g. 6. Patent Owner concludes that Stopler's phase scrambling "must have a different purpose than the claimed phase scrambling because [it] . . . cannot reduce PAR." *Id.* at 7.

We addressed this argument and found it unpersuasive. Dec. 18–22. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

C. Allegedly Misapprehended or Overlooked Testimony

Patent Owner quotes page 21 of our Decision and argues that "there are several inaccuracies." Req. Reh'g 8–12. These arguments are based, in part, on a mischaracterization of our claim construction as *requiring* the same amount of rotation of the phase of each of the QAM symbols in a DMT symbol. *See, e.g., id.* at 8 ("First, a DMT symbol cannot be phase scrambled as that term is used in the claims by having its component QAM symbols rotated by the *same* amount."), 9 ("as interpreted in the FWD ('i.e.,

rotates by the same amount, the phase of a plurality of QAM symbols.’).”). Our construction of “scrambling . . . a plurality of carrier phases” does not *require* rotating by the same amount. And as we applied the prior art, to the totality of the claim language, it is clear that we construed the totality of the claim language to require the phases of the carriers of the multi-carrier signal be rotated by varying amounts. For example, our Decision states

> Stopler further teaches that, “a phase scrambling sequence is applied to the output symbols,” including “all symbols, not just the overhead symbols.” *Id*. at 12:25–28. Patent Owner’s expert, Dr. Short, agreed that Stopler is referring to phase scrambling QAM symbols. Reply 16–17 (citing Ex. 1027 (Tellado Dep.), 54:17–55:3, 55:19–24, 58:6–8, 59:9–12, 60:15–22). Stopler further teaches that a “scrambling sequence may be generated by a pseudorandom generator” that generates pairs whose sum “is used to select the amount of rotation to be applied to the symbol,” singular; not “symbols” plural. Ex. 1012, 12:28–36. Thus, the most intuitive reading of Stopler supports Petitioner’s contention that QAM Mapper and Phase Scrambler 82 determines an amount of rotation and rotates the phase of a single QAM symbol by that amount.

Dec. 21–22.

Patent Owner also objects to our characterization of Dr. Short’s testimony as “admit[ing] that Stopler does not describe phase scrambling DMT symbols” (Dec. 21 (citing Ex. 1027, 60:11–14)). Req. Reh’g 9 (regarding Ex. 1027, 60:11–14). That testimony is as follows:

> Q. Well, you would agree with me that [Stopler] doesn’t expressly teach applying the phase scrambler to the DMT as a whole?
>
> A. I would agree with that.

Ex. 1027, 60:11–14. We acknowledge that Dr. Short testified that he *understands* Stopler to be rotating all of the QAM symbols within a

DMT symbol by the same amount, but the point made in our Decision remains: Dr. Short clearly conceded, however, that Stopler does not *expressly teach* applying the phase scrambler to the DMT symbol as a whole. Dec. 21 (citing Ex. 1027, 60:11–14).

Patent Owner also argues that we misapprehended its argument that Stopler would adjust the phases of QAM symbols *over time* in order to reduce narrowband noise. Req. Reh'g 10 (citing PO Resp. 39 ("According to a second narrowband-noise-reducing technique, Stopler addresses narrowband noise at the frequency of an overhead pilot carrier by scrambling the phase of the pilot carrier over time from one DMT symbol to the next, *i.e.*, by ***inter***-symbol phase scrambling. *See* Ex. 2003 at ¶ 82."). As we noted in our Decision, however, Stopler teaches and Petitioner relies "not just on the scrambling of 'overhead signals, such as pilot tones,' (Pet. 12) but on the scrambling of *all* QAM symbols. Because neither Petitioner's argument nor Stopler's teaching of phase scrambling is limited to pilot tones, Patent Owner's argument is not persuasive." Dec. 23.

Patent Owner also argues that we misapprehended its burden by noting that "Patent Owner identifies nothing in Stopler to suggest that, in an alternative embodiment with a multicarrier modulator, QAM Mapper and Phase Scrambler 82 do not supply a plurality of phase-scrambled QAM symbols for modulation onto the plurality of carriers in the, e.g., DMT symbol." Req. Reh'g 10–11 (quoting Dec. 21). Petitioner has the burden of persuasion to prove unpatentability by a preponderance of the evidence. *See* 35 U.S.C. § 316(e); *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.*, 800 F.3d 1375, 1379 (Fed. Cir. 2015). For this element, we explained how Petitioner satisfied that burden based, *inter alia*, on express disclosure in

Stopler. Dec. 21–22. The sentence to which Patent Owner objects merely notes that, even assuming Stopler works as Patent Owner argues in an embodiment with a single-carrier modulator, that does not persuasively rebut the express disclosure upon which Petitioner relies. Accordingly, we are not persuaded that we misapprehended Patent Owner's burden.

Patent Owner also argues it was denied the opportunity to file a sur-reply. Req. Reh'g. 11–12. Patent Owner was, however, granted an opportunity to identify allegedly new arguments and evidence in Petitioner's Reply (Paper 21), and we considered the identified portions when reaching our Decision (Dec. 24 n.7). Although the "listing" format required Patent Owner to be efficient in its identification and required Petitioner to be efficient in its responsive paper, these papers provided "the information necessary to make a reasoned decision" (*Ultratec, Inc. v. CaptionCall, LLC*, 872 F.3d 1267, 1273 (Fed. Cir. 2017)) about whether the arguments and evidence raised in reply were outside the scope of a proper reply.

D. Shively's PAR

Finally, Patent Owner argues that we misapprehended or overlooked its argument that Shively's PAR would not be so "increased" or "high" that it resulted in clipping, as would be needed before a person of ordinary skill in the art had reason to modify Shively. Req. Reh'g 12–15. We addressed this argument and found it unpersuasive. Dec. 27–28. Mere disagreement with the Board's conclusion is not a proper basis for rehearing. It is not an abuse of discretion to have made a conclusion with which a party disagrees.

Moreover, Patent Owner alleges that "the FWD characterizes Shively as having a 'high' or 'increased' PAR." Req. Reh'g. 13 (citing Dec. 27–28). That is false. Our Decision states that it is undisputed that Shively's

technique "will increase PAR" (Dec. 27–28), but does not characterize Shively as having a "high" or "increased" PAR.[4] Our Decision relies upon page 28 of Patent Owner's Response (Paper 12), which concedes that "Shively's 'spreading' technique will contribute a small uptick in clipping probability." Patent Owner does not dispute, in its Request for Rehearing, Shively's technique *increases* PAR.

With respect to Patent Owner's argument that "there is no PAR *problem* presented by Shively" (Req. Reh'g. 13) and "the only PAR problem in this case relates to clipping" (*id.* at 14), we considered that argument and found it unpersuasive. Dec. 27–28. As we noted, "Petitioner's reason to combine does not depend on the PAR increase exceeding some specific numeric threshold," "there also is no dispute that equipment designed to handle a higher PAR can be larger, more expensive, and more power hungry than equipment designed to handle a lower PAR," and, therefore, "a person of ordinary skill in the art . . . would have been motivated to reduce PAR regardless of whether Shively's technique resulted in clipping." *Id*. In other words, as we explained in our Decision, Shively's PAR need not result in clipping in order to motivate a person of ordinary skill in the art because we are persuaded such a person would have been motivated sufficiently to reduce PAR by the benefit of being able to use smaller, less expensive, less power hungry components.

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[4] In a sentence summarizing Petitioner's position, our Decision states, "*Petitioner alleges* that Shively's proposed system would have an 'increased' or 'high' PAR." Dec. 27 (quoting Pet. 13–14) (emphasis added). It should be obvious, however, that a summary of Petitioner's allegation is not a characterization by the panel.

II. ORDER

Accordingly, it is it is ORDERED that Patent Owner's Request for Rehearing is *denied*.

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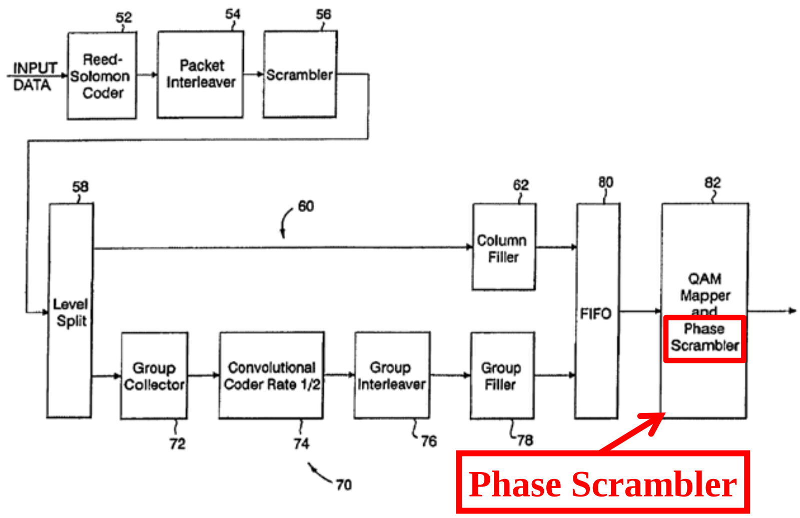
B. Overview of Stopler

58. "Stopler" is U.S. Patent No. 6,625,219 (Ex. 1012). Like Shively, Stopler describes multicarrier data transmission, including specifically the use of discrete multitone transmission (DMT). Ex. 1012, 1:50-51. Stopler explains that DMT is one type of multitone modulation, which involves "a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel." Ex. 1012, 1:9-11 & 1:42-45.

Stopler explains that its multitone modulation techniques are compatible with various signal modulation technologies, an example of which employs 256 carriers positioned at different frequencies. Ex. 1012, 1:42-61; 12:55-57. Stopler also explains that its signal transmission scheme may implement techniques of DSL standards such as "ADSL (Asymmetric Digital Subscriber Line)." Ex. 1012, 9:37-41, 12:21-24.

59. Stopler also explains that some of the available carriers may be reserved for the transmission of overhead signals (also called overhead symbols), such as pilot tones. Ex. 1012, 10:60-62 & 12:51-54. To randomize these overhead channels, Stopler employs a phase scrambler. Ex. 1012, 12:24-26. A POSITA would have understood that the values transmitted in an overhead channel may not be random, and in fact, may be highly structured. Without the phase scrambler, the structured nature of the overhead channel could contribute to an increase in the

peak-to-average power ratio of the transmitter. Stopler illustrates its phase scrambler, as shown in FIG. 5, below:



Ex. 1012, FIG. 5 (Annotated)

60. The phase scrambler as described by Stopler is implemented to "randomize" all symbols, including the data symbols. Ex. 1012, 9:34-47, 12:24-45. A POSITA would have recognized that a purpose for implementing the phase scrambler to randomize the data symbols would be to reduce the PAR of transmitted signals.

61. Stopler is analogous art to the '243 patent because both Stopler and the '243 patent are in the same field of endeavor (data communications and processing). Ex. 1012, 1:7-8; Ex. 1001, Abstract.

C. Reasons to Combine Shively and Stopler

62. It would have been obvious to a POSITA to combine Shively and Stopler because the combination is merely the use of a known technique to improve a similar device, method or product in the same way.

63. A POSITA would have recognized that by transmitting redundant data symbols on multiple carriers, Shively's transmitter would suffer from an increased peak-to-average power ratio. This increase is due to the fact that the overall transmitted signal in a multicarrier system is essentially the sum of its multiple subcarriers. When N subcarrier signals with the same phase and amplitude are added together, they have a peak power which is N times greater than their individual maximum powers.

64. Since Shively's subcarriers use quadrature amplitude modulation (QAM)—which encodes bits to be transmitted by modulating the phase and amplitude of the subcarrier—transmitting the same one or more bits on two different subcarriers causes those subcarriers to have the same phase and amplitude. By transmitting the same bits on multiple subcarriers, Shively creates a situation where those multiple subcarriers will be phase-aligned. Having phase-aligned subcarriers causes a high peak-to-average power ratio (PAR), since all of the subcarriers add up coherently at the same time. I note that the '243 patent

acknowledges that it was known for a high PAR to result from transmitting the same data on multiple carriers:

> If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, ***multiple carrier signals are used to modulate the same input data bits***, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a -90 degree phase characteristic of the DMT carrier signal).

Ex. 1001, 2:15-25.

65. I agree that a POSITA would have immediately recognized that Shively's redundant transmission technique would negatively impact the PAR.

66. A POSITA would have been familiar with the problems created by a high PAR. Among the problems is the need for transmission components, such as amplifiers and digital-to-analog converters, with a linear response over a large dynamic range. To the extent that such components existed, they were expensive and highly inefficient. Less capable components would cause non-linear signal distortion, such as from amplitude clipping, resulting in data transmission errors. Since a high PAR brings numerous disadvantages, a POSITA would have sought out an approach to reduce the PAR of Shively's transmitter.

67. Stopler provides a solution for reducing the PAR of a multicarrier transmitter. Specifically, Stopler teaches that a bit scrambler followed by a phase

scrambler can be employed to randomize the phase of the individual subcarriers. Ex. 1012, 12:24-28. A POSITA would have recognized that by randomizing the phase of each subcarrier, Stopler provides a technique that allows two or more subcarriers in Shively's system to transmit the same one or more bits, but without those two or more subcarriers having the same phase. Since the two subcarriers are out-of-phase with one another, the subcarriers will not add up coherently at the same time, and thus the peak-to-average power ratio for the overall system will be less than in Shively's original system.

68. Combining Stopler's phase scrambler into Shively's transmitter would have been a relatively simple and obvious solution to reduce Shively's PAR.

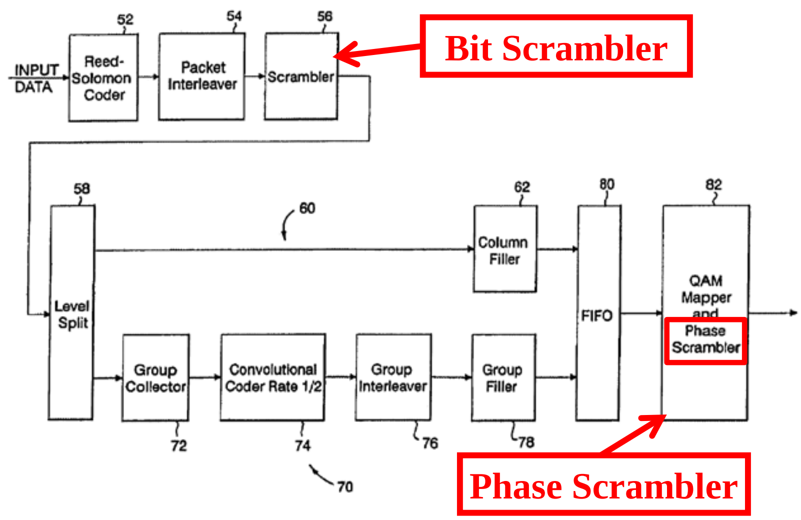
69. Market forces would have prompted the development of multicarrier communications devices, such as Digital Subscriber Line (DSL) modems, employing both redundant bit transmission and phase scrambling. As Shively explains, effective use of redundant bit transmission actually *increases* the available bandwidth by exploiting subcarriers that would otherwise be wasted (unused). Ex. 1011, 16:7-10. Combining redundant bit transmission with Stopler's phase scrambling technique would have allowed the development of faster DSL modems *without* requiring more complex (and expensive) circuitry for handling an increased peak-to-average power ratio.

70. Thus, it would have been obvious to combine Shively with Stopler as the combination is merely the use of a known technique to improve a similar device, method or product in the same way.

D. Detailed Analysis

71. The following claim chart describes how Shively in view of Stopler renders obvious each and every element of claims 1-3, 7-9, 13-16 and 20-22 of the '243 patent.

U.S. Patent No. 9,014,243	**Shively in view of Stopler**
Claim 1	
[1.0] A method, in a multicarrier communications transceiver comprising	Both Shively and Stopler independently render obvious this preamble. **First,** Shively teaches performing a method in a multitone communication system: It is an object of the invention to ***provide a method for transmission in a multitone communication system*** together with an algorithm for allocating bits in the system. Ex. 1011, 3:28-29. Shively teaches that it was known to employ multicarrier communications techniques, such as discrete multitone (DMT) modulation, using a DSL modem: This invention relates to ***discrete multitone transmission (DMT) of data by digital subscriber loop (DSL) modems*** and more specifically to the allocation of bits, respectively, to the discrete multitones. Ex. 1011, 1:5-8.

<table>
<tr>
<td></td>
<td>
<blockquote>communication with a remote transceiver 14 over a communication channel 18 using a transmission signal 38 having a plurality of carrier signals. The DMT transceiver 10 includes a DMT transmitter 22 and a DMT receiver 26.</blockquote>
Ex. 1001, 1:25-30.
Thus, a POSITA would have recognized that both Shively and Stopler describe multicarrier communications apparatuses, such as modems, and that Shively and Stopler further describe methods performed by such modems. Shively and Stopler therefore independently render obvious “method, in a multicarrier communications transceiver.”
</td>
</tr>
<tr>
<td>[1.1] a bit scrambler followed by a phase scrambler, comprising:</td>
<td>
Stopler renders obvious this limitation.
Stopler teaches that the transmitter portion of its multicarrier communications apparatus (the “transceiver” of portion [1.0]) includes scrambler 56 followed by a QAM mapper and phase scrambler 82:


Ex. 1012, FIG. 5 (Annotated)
Scrambler 56 is a bit scrambler because it
</td>
</tr>
</table>

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SUMMARY

- Signal Processing and Digital Communications expert: Architected, designed and optimized, pre/post tapeout, numerous complex and high-throughput physical layers in both wireless and wired technologies using OFDM/DMT, QAM/PAM and MIMO.
- Team leader: built and led PHY/Systems teams to design, develop and map into hardware as well as troubleshoot algorithms within digital, analog, cost metrics and schedule constraints.
- Author of intellectual property with over 60 issued and filed patents.
- Key contributor to IEEE standardization efforts in 802.16 (WiMAX) and 802.3an (10GBase-T).

EDUCATION

Stanford University

Ph.D. in Electrical Engineering 1994 – 1999
Dissertation Topic: Peak to Average Power Reduction for Multicarrier Modulation
Advisor: Prof. John M. Cioffi

M.S. in Electrical Engineering 1993 – 1994
Emphasis: Signal processing and Digital Communications

University of Santiago de Compostela (Vigo), Spain 1988 – 1992

B.S. in Telecommunication Engineering (top GPA in Spain)

PROFESSIONAL EXPERIENCE

Rasa Networks

VP Technology 2014 – present

- As the 2nd employee of this venture backed start-up, co-lead the transformation to a leading SaaS WiFi analytics company.
- Hired and lead a small team of Wireless and Data Science experts to derive insights from WiFi metadata to improve connectivity, reliability and performance and provide actionable feedback to WiFi network operators.

US006144696A

United States Patent [19]

Shively et al.

[11] **Patent Number: 6,144,696**

[45] **Date of Patent: Nov. 7, 2000**

[54] **SPREAD SPECTRUM BIT ALLOCATION ALGORITHM**

[75] Inventors: **Richard Robert Shively**, Convent Station; **Ranjan V. Sonalkar**, North Caldwell, both of N.J.

[73] Assignee: **AT&T Corp.**, New York, N.Y.

[21] Appl. No.: **09/000,842**

[22] Filed: **Dec. 31, 1997**

[51] **Int. Cl.**[7] **H04B 1/38**

[52] **U.S. Cl.** **375/222**; 375/225; 370/391; 370/358

[58] **Field of Search** 375/222, 219, 375/225; 455/127, 509; 370/391, 358

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Primary Examiner—Stephen Chin
Assistant Examiner—Mohammad Ghayour

[57] **ABSTRACT**

High transmission capacity in a twisted pair signal line, where power is limited by a power spectral-density mask and an aggregate signal power constraint, is obtained by: (1) allocating data to multitone sub-bands according to a lowest marginal power-cost per bit scheme and (2) in an environment where an aggregate power budget remains after all bits have been allocated to all sub-bands with sufficient margins to carry a bit, assigning additional bits to sub-bands with otherwise insufficient power margins to carry a single bit, by frequency-domain-spreading a single bit across several sub-bands at correspondingly reduced power levels, to permit the otherwise unacceptable noise levels to be reduced on average by despreading at the receiving end. Another feature of the invention, applicable in an environment in which multiple interfering channels are employed, provides increased signal throughput by (3) transmitting coherently in a number of multitone sub-bands, identical blocks of data, with the number of multitone sub-bands being equal to a number of interfering channels and multiplying the signal carried by corresponding sub-bands in the separate interfering channels by a different respective vector from an orthonormal basis set so that near-end cross-talk is eliminated upon despreading at the receiving end.

7 Claims, 5 Drawing Sheets

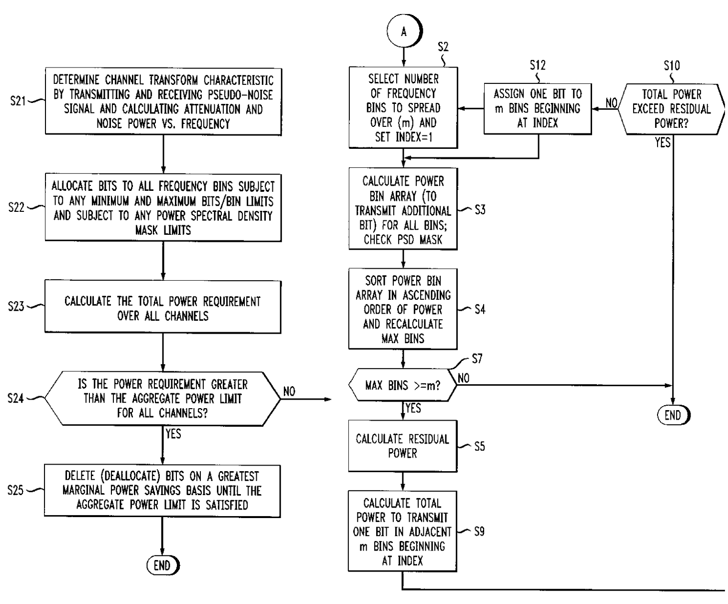


FIG. 1

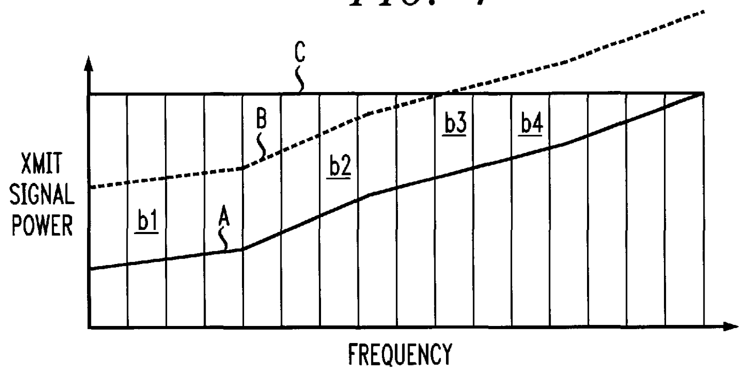


FIG. 2

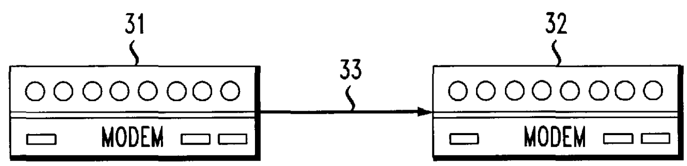


FIG. 3

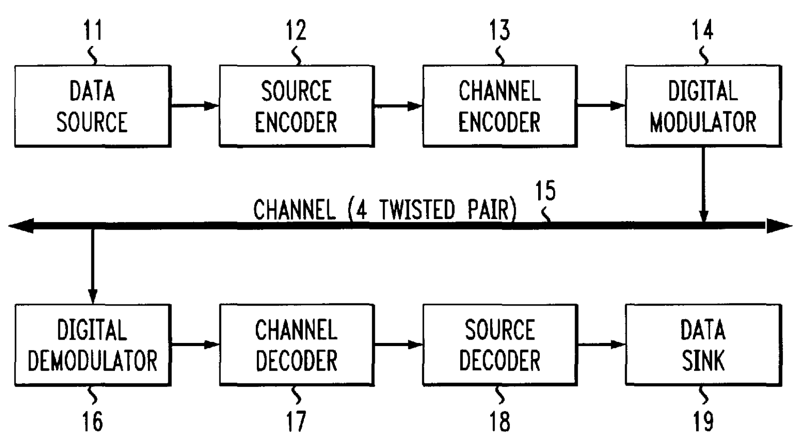


FIG. 4

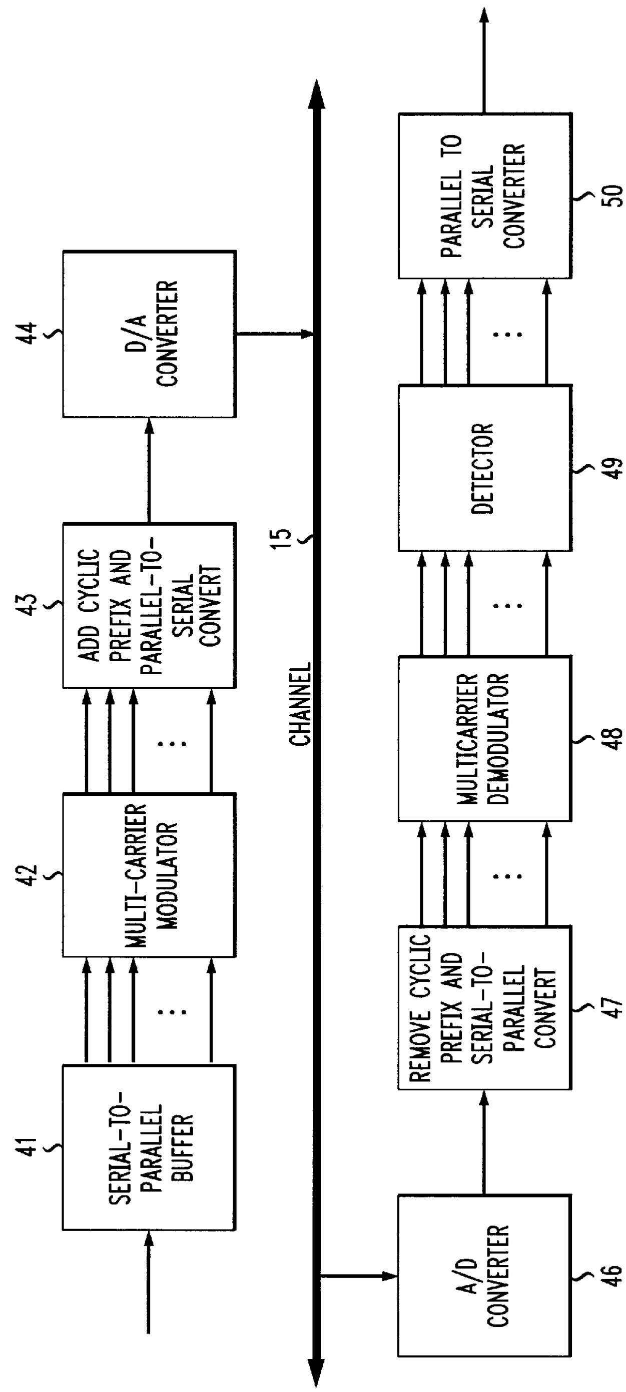

SERIAL-TO-PARALLEL BUFFER
41
MULTI-CARRIER MODULATOR
42
ADD CYCLIC PREFIX AND PARALLEL-TO-SERIAL CONVERT
43
D/A CONVERTER
44
CHANNEL
15
A/D CONVERTER
46
REMOVE CYCLIC PREFIX AND SERIAL-TO-PARALLEL CONVERT
47
MULTICARRIER DEMODULATOR
48
DETECTOR
49
PARALLEL TO SERIAL CONVERTER
50

FIG. 5

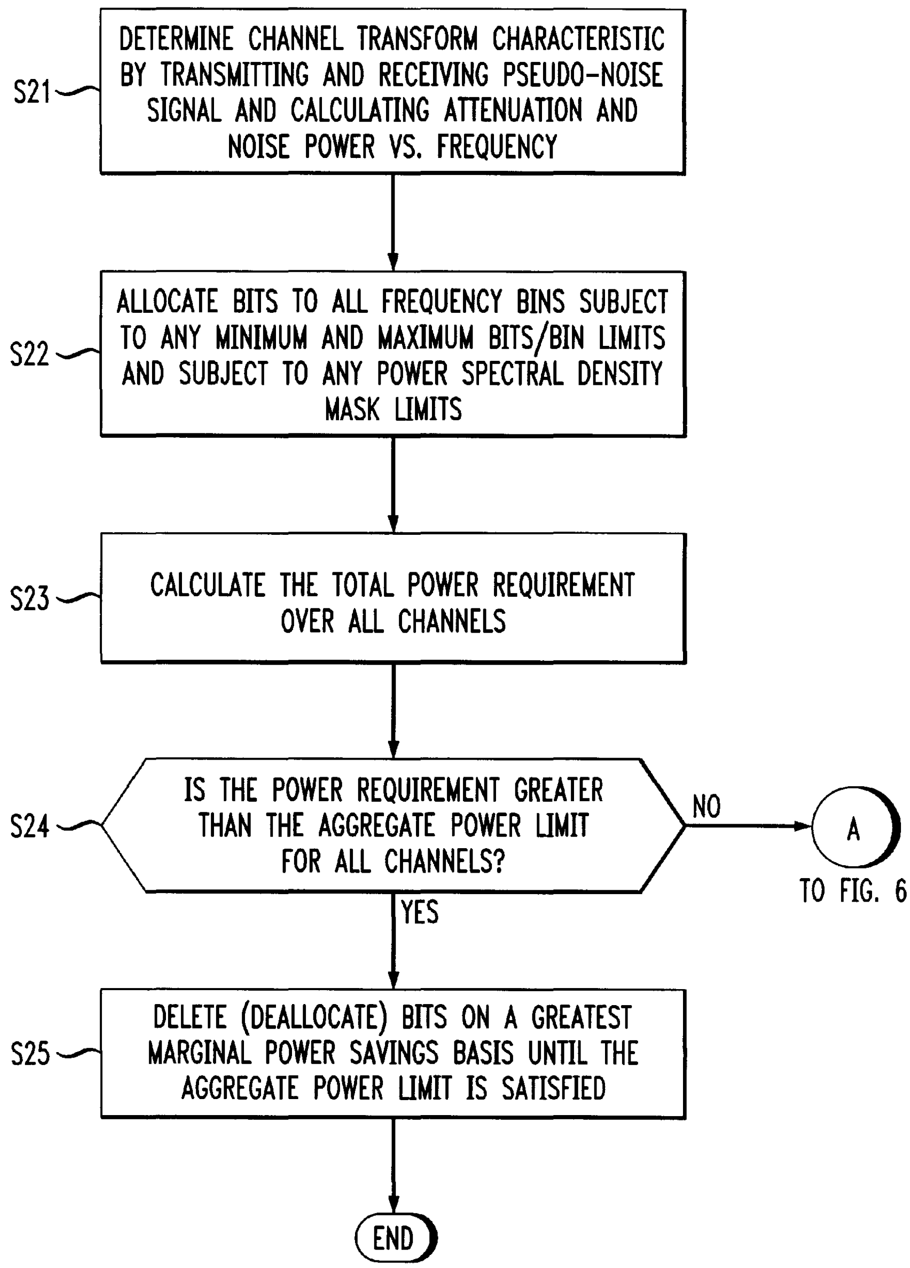

S21
DETERMINE CHANNEL TRANSFORM CHARACTERISTIC BY TRANSMITTING AND RECEIVING PSEUDO-NOISE SIGNAL AND CALCULATING ATTENUATION AND NOISE POWER VS. FREQUENCY
S22
ALLOCATE BITS TO ALL FREQUENCY BINS SUBJECT TO ANY MINIMUM AND MAXIMUM BITS/BIN LIMITS AND SUBJECT TO ANY POWER SPECTRAL DENSITY MASK LIMITS
S23
CALCULATE THE TOTAL POWER REQUIREMENT OVER ALL CHANNELS
S24
IS THE POWER REQUIREMENT GREATER THAN THE AGGREGATE POWER LIMIT FOR ALL CHANNELS?
NO
A
TO FIG. 6
YES
S25
DELETE (DEALLOCATE) BITS ON A GREATEST MARGINAL POWER SAVINGS BASIS UNTIL THE AGGREGATE POWER LIMIT IS SATISFIED
END

FIG. 6

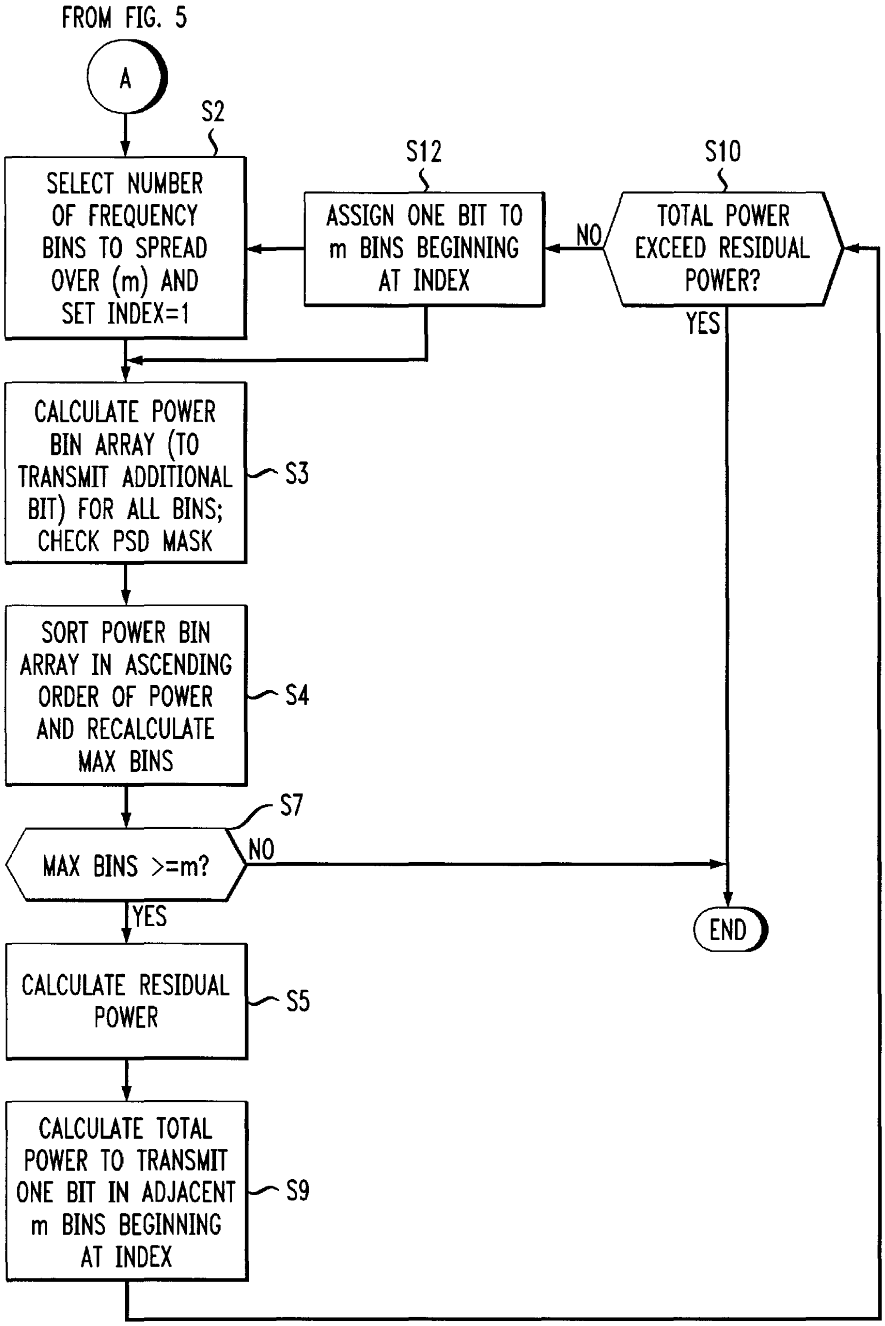
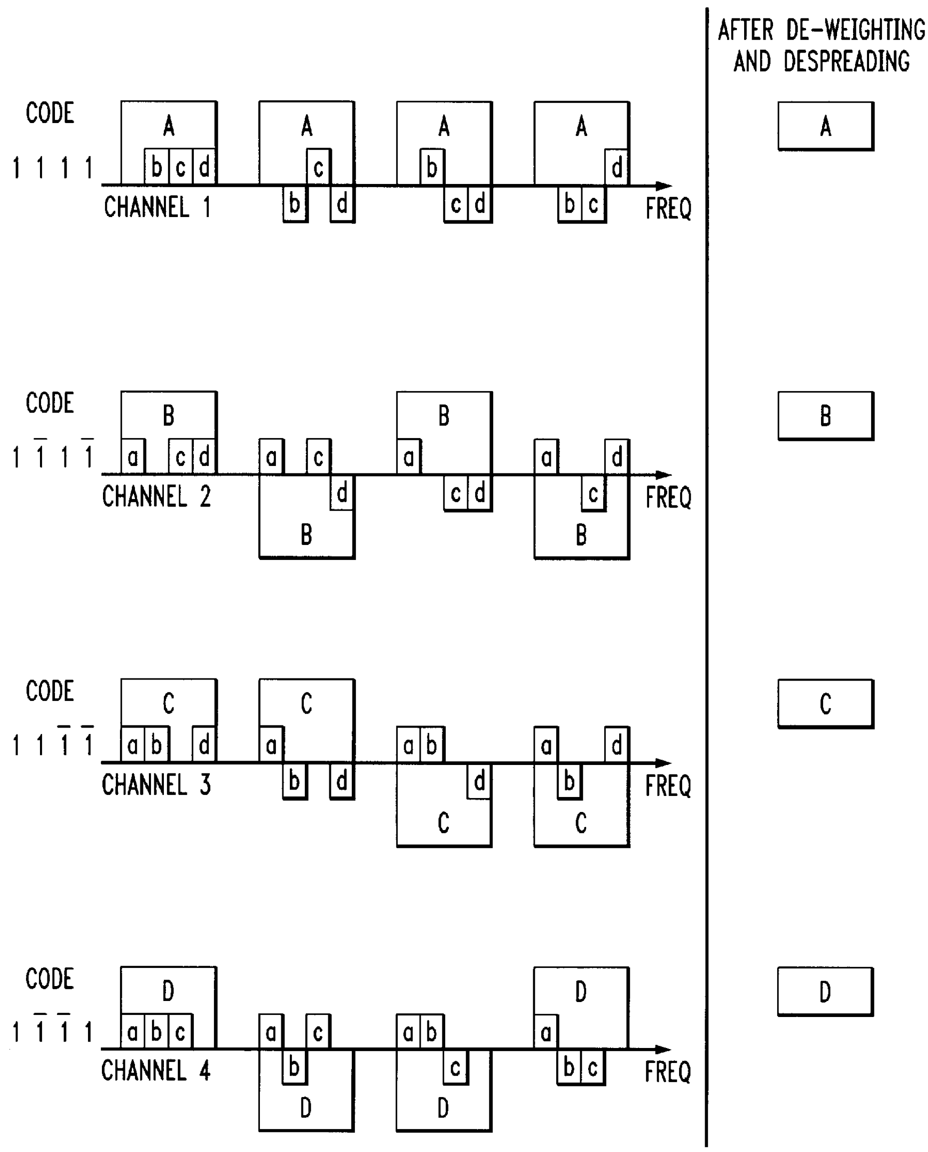

FROM FIG. 5
A
S2
SELECT NUMBER OF FREQUENCY BINS TO SPREAD OVER (m) AND SET INDEX=1
S12
ASSIGN ONE BIT TO m BINS BEGINNING AT INDEX
NO
S10
TOTAL POWER EXCEED RESIDUAL POWER?
YES
CALCULATE POWER BIN ARRAY (TO TRANSMIT ADDITIONAL BIT) FOR ALL BINS; CHECK PSD MASK
S3
SORT POWER BIN ARRAY IN ASCENDING ORDER OF POWER AND RECALCULATE MAX BINS
S4
S7
MAX BINS >=m?
NO
YES
END
CALCULATE RESIDUAL POWER
S5
CALCULATE TOTAL POWER TO TRANSMIT ONE BIT IN ADJACENT m BINS BEGINNING AT INDEX
S9

FIG. 7


AFTER DE-WEIGHTING AND DESPREADING
CODE
1 1 1 1
CHANNEL 1
FREQ
A
CODE
1 $\bar{1}$ 1 $\bar{1}$
CHANNEL 2
FREQ
B
CODE
1 1 $\bar{1}$ $\bar{1}$
CHANNEL 3
FREQ
C
CODE
1 $\bar{1}$ $\bar{1}$ 1
CHANNEL 4
FREQ
D

SPREAD SPECTRUM BIT ALLOCATION ALGORITHM

TECHNICAL FIELD

This invention relates to discrete multitone transmission (DMT) of data by digital subscriber loop (DSL) modems and more specifically to the allocation of bits, respectively, to the discrete multitones.

BACKGROUND OF THE INVENTION

In digital communication systems employing multi-channel or multi-carrier transmission, the most effective allocation of bits to the channels has been discussed in the literature. The well-known solution from information theory, analogized to pouring water over a terrain defined by the noise/attenuation of the channel transform characteristic, has been found to insure efficient use of signal power within limits defined by aggregate power and power spectral density mask limits. However, the method in some instances may not go as far as possible in exploiting available power imposed by these limits.

For heuristic purposes, the prior art and the invention are discussed in terms of N quadrature amplitude modulation (QAM) channels with a uniform symbol rate and a non-uniform (unique to each channel) QAM constellation. QAM, a form of combined amplitude and phase modulation, represents k-bit sets of data by modulating two (orthogonal) quadrature carriers, cos $2\pi f_c t$ and sin $2\pi f_c t$ to generate a pulse whose phase and amplitude convey the encoded k-bits of information. The QAM signal tone can be viewed as a phasor in the complex plane, each distinguishable phasor representing a unique state of the tone identified with one unique value in a range. Thus, if the channel and signal power are such that 4 separate phasors can be reliably distinguished, the scheme allows two bits to be represented. For 3 bits to be represented, 8 phasors must be distinguished and so on. The number of different phasors or states that are distinguishable in a single tone (pulse), the QAM constellation, is limited by the signal to noise ratio of the channel and limits imposed by external standards as discussed below.

In a DMT modem, a transmission frequency band is separated into N sub-bands or frequency bins, each corresponding to one QAM channel. In a non-ideal channel each sub-band has a different capacity as a result of the variation of noise and attenuation with frequency. In addition, external standards impose limits on the aggregate power of a signal (the power applied in all sub-band channels) and a cap on the power as a function of frequency defined by a power spectral density mask.

The power spectral density mask may be dictated by the standard used in a particular country implementing the standard (such as A.N.S.I. standard T1.413-1995). The mask may also be a design constraint intentionally imposed by a modem designer for some other reason. For example, a designer may intentionally impose a constraint that no more than n bits are to be transmitted on transmit channel frequency. Similarly, the designer may impose a constraint that a minimum of bits (or no bits) must be transmitted on a particular tone or frequency. For example, the power limit for frequencies or tones between 0 and 200 kilohertz must be less than --40 dBm/Hz (a power level referenced to one milliwatt over 1 Hz bandwidth). Above 200 kHz (to frequencies in the megahertz of spectrum), the constraint may be −34 dBm/Hz.

Referring to FIG. **1**, the attenuation +noise characteristics of a medium can be graphically represented by a floor in a

power spectral graph. The lower curve, the channel transform characteristic A represents this floor, that is, the combined effect of noise and attenuation as a function of frequency. A certain margin of power is required to meet or exceed the minimum threshold of a signal for reliable data transmission. In other words, the power of a signal in a given sub-band must be sufficiently high to carry a minimal (1-bit) QAM tone to obtain a predefined bit error rate. The minimum margin, that required to transmit a single bit, is represented by curve B. Curve C represents the limits imposed by a power spectral density mask imposed by an external communications standard. The other limit is on the aggregate power, also defined by an external communication standard, e.g., ANSI Standard T1.413-1995 limits the total power for all sub-bands to 100 mWatts. Some coding techniques, such as Wei code described in American National Standard for Telecommunications—Network and Customer Installation Interfaces—Asymmetric Digital Subscriber Line Metallic Interface, ANSI T1.413-1995, may also require a minimum number of bits in a frequency band if the band is to convey any information at all. In other words, if the power spectral density mask limit may require that less energy be used than the minimum required to transmit a single bit.

Note that the minimum allowable size of the power margin is, in part, arbitrary since, to an extent, it is defined in terms of some a priori rules and technical criteria (which are arbitrary to the extent that they establish a dividing line between acceptable and unacceptable error rates; Bit Error Rate or BER) for the given communication system. Note also that the size of the margin available for a given sub-band corresponds to the dimension of the constellation that can be represented in a signal carried in that QAM channel. That is, the larger the margin in a band, the greater the number of states that can be reliably distinguished in that band and the larger the constellation that can be used.

The above context creates a bit-allocation problem. That is, given the constraints, how should bits be allocated among the available QAM channels to provide the highest possible data rates? DSL modems that use DMT modulation concentrate the transmitted information in the frequency sub-bands that have the minimum attenuation and noise. The optimum distribution of transmission power is obtained by distributing the power according to the well-known “water pouring” analogy as described in Robert G. Gallagher, Information Theory and Reliable Communication, John Wiley and Sons, New York, 1968. Such optimal distribution requires a strategy for allocating bits to the sub-bands for the idealized situation where the channel sub-bands approach zero width ($\Delta f \rightarrow 0$). For discrete bits, the applicable metaphor could be described as an ice-cube pouring analogy.

DSL technology was conceived to maximize the throughput on twisted pair copper wiring with attendant background noise, time-variant Far End Cross Talk (FEXT) and Near End Cross Talk (NEXT). To determine the transform characteristic of the channel, the modems negotiate during an initial channel signal-to-noise ratio (SNR) estimation procedure. During the procedure, the transmitter sends a known pseudo noise (PN) signal. The receiver computes the characteristics of the received signal in the form of a ratio N_k/g_k, where g_k is the channel gain (inverse of the attenuation) in frequency band k and N_k is the noise power in the band k. The literature contains many algorithms for determining the power distribution across the full frequency bandwidth for maximum data throughput. As noted above, the optimum approach for non-uniform Gaussian noise channel divided such that each band can be considered an additive white

Gaussian noise channel has been proved to be the "water pouring" algorithm of power distribution. In this case, the g_k/N_k. Profile is compared to a terrain and the available aggregate power limit to a fixed supply of water poured over the terrain. The depth of the water corresponds to the power spectral density. The water pouring analogy is inappropriate to allocation of power in digital channels intended for transmission of binary data (bits).

According to one method of allocating bits (John A. C. Bingham, *Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come*, IEEE Communications Magazine, May 1990, pp5–14), frequency sub-bands or bins are "filled" with data bits one bit at a time. A bit is added to the bin for which the marginal power cost is the lowest. That is, a bit is added to the bin such that transmission in that bin is the least expensive, relative to an additional bit in any other bin, in terms of power needed for the resulting signal constellation to be received at a predefined BER. The filling procedure is followed until the total Power Budget is used up. Since power can only be allocated in discrete amounts corresponding to each bit, the procedure is likened, as mentioned, to an ice-cube filling procedure rather than a water-filling procedure.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide a method for transmission in a multitone communication system together with an algorithm for allocating bits in the system.

It is an object of the invention to provide a method for transmission in a multitone communication system subject to an aggregate signal power constraint together with an algorithm for allocating bits in the system.

It is an object of the invention to provide a method for transmission in a multitone communication system subject to a signal-power spectral density mask constraint together with an algorithm for allocating bits in the system.

It is an object of the invention to provide a method for transmission in a multitone communication system subject to an aggregate signal power constraint and a signal-power spectral density mask constraint together with an algorithm for allocating bits in the system.

It is another object of the invention to provide a method for transmitting data over multiple interfering channels.

It is another object of the invention to provide a method for transmitting data over multiple interfering channels and a method for reducing interference between the interfering channels.

It is another object of the invention to reduce near end cross talk between DSL modems communicating over the same cable.

Briefly, high transmission capacity in a twisted pair signal line, where power is limited by a power spectral-density mask and an aggregate signal power constraint, is obtained by: (1) allocating data to multitone sub-bands according to a lowest marginal power-cost per bit scheme and (2) in an environment where an aggregate power budget remains after all bits have been allocated to all sub-bands with sufficient margins to carry at least one bit, assigning additional bits to sub-bands with otherwise insufficient power margins to carry a single bit, by frequency-domain-spreading a single bit across several sub-bands at correspondingly reduced power levels, to permit the otherwise unacceptable noise levels to be reduced on average by despreading at the receiving end. In an environment in which multiple interfering channels are employed, signal throughput is increased by (3) forming a number of sub-bands for spreading blocks of data that is equal to a number of interfering channels and multiplying the signal carried by corresponding sub-bands in the separate interfering channels by a different respective vector from an orthonormal basis set so that near-end cross-talk is eliminated upon despreading at the receiving end.

Note that "spreading" as used in the present application, refers to a process applied at a stage where the signal is decomposed into spectral elements, so that it can be applied selectively to frequency components, in contrast to conventional spreading found in, for example, wireless (cellular) telephony, where spreading is applied to the signal time series, and affects (spreads) all elements of the spectrum equally as a consequence.

According to the invention bit allocation may be performed to optimize throughput within aggregate power and power spectral density mask limits. Some method, such as the approach identified above with the water pouring analogy, may be used for this bit allocation. The process of bit allocation will be limited either by the mask limit or the aggregate signal power limit. If after efficient allocation, the total signal power is less than the aggregate power limit, there will usually be unused sub-bands. These unused sub-bands were rejected in the initial bit-allocation process because the available power margin in them was insufficient to transmit a single bit. That is, the channels were identified as unusable because transmitting a single bit was found to exceed the mask limit for the channel. In this case, where the bit allocation process is limited by the mask, the channels with low power margins are used to transmit information by spreading a single block of data (one or more bits) over multiple channels and then despreading them at the receiver.

The device of spreading and despreading over multiple channels also provides a mechanism for reducing near end cross talk (NEXT). The context to which this device applies is a packet consisting of I interfering channels and nI carriers in each channel. For example, the channels could be four wire pairs, in each, some multiple of four carriers are used to convey information by spreading a single block over each of four carriers to transmit, and then despreading at the receiver. At the transmitter, however, the signals in each interfering channel are multiplied by one element of an I-dimensional orthogonal code (such as a binary code). At the receiving end, the signals are multiplied again by the respective opposite orthogonal code and then despread. The process of despreading not only reduces incoherent noise as in the embodiment discussed above, but it also substantially eliminates NEXT because the interference generated in all the frequency channels, being derived from orthogonal set, cancel each other. Thus in a channel of four twisted pairs of wires, each pair transmits a different block of data but every different block is spread over four carriers in a given wire pair. The signal transmitted over each of the four wire pairs is assigned one of four orthogonal codes. Summing each block spread over the four frequency channels causes mutual cancellation of the four induced cross-talk signals of the four wires that were multiplied by the four orthogonal codes.

Discrete Multitone (DMT) modulation serves as a framework to demonstrate the spreading process. An input data stream is segmented into small blocks of bits, and each such block is re-expressed as a complex number. For example, a constellation of 16 possible discrete complex number values can be used to convey 4 bits, since 16 different states are required to represent 4 bits. The resultant array of complex numbers is inverse-Fourier transformed to synthesize a time

series, Y(t), that represents a sum of multiple distinct sinusoids. (A complex conjugate array of complex numbers is used as an input to the Inverse Fast Fourier Transform process to assure a real resultant time series.)

Each of the complex numbers used to encode data therefore plays the role of a complex spectral coefficient. That is, each defines the amplitude and phase of one of the orthogonal sinusoids included in the transmitted waveform. The number of discrete points in the constellation for each of the bands is a consequence of the measured attenuation and noise level in that frequency band, based on a bit-allocation process that need not be described here.

In both of the above schemes, the signal power in each frequency carrier is reduced in proportion to the number of carriers used. Also, in both schemes, the information relating to the number of bits per block, the frequency channels over which blocks are to be spread, etc. must be shared between the transmitter and the receiver. Regarding the latter scheme, the transmitter and receiver must also share the orthogonal codes to be used for each twisted pair, though these can be established on a permanent basis.

According an embodiment, the invention provides a transmitting modem that receives digital data from a data source and modulates separate carriers to represent the digital data. The modulated signal is applied to a channel connected to a receiving modem. The channel is subject to a power spectral density mask. The transmitting modem includes first, second, and third signal modulators, each with an input. The modem also has a signal combiner with a combined output connected to the channel and a serial-to-parallel converter connected to the data source and to each of the first, second, and third signal modulator inputs. The connection is such that the digital data from the data source is converted to multiple parallel streams applied respectively to the first, second, and third signal modulators. Each of the first, second, and third signal modulators has a respective output connected to the signal combiner such that a sum of output signals of the first, second, and third signal modulators is applied to the channel. A transfer characteristic of the channel is such that a first minimum power required to represent a specified minimum number of bits by modulating in a first frequency sub-band falls below the power spectral density mask and such a that a second minimum power required to represent a second specified minimum number of bits by modulating in each of second and third frequency sub-bands exceeds the power spectral density mask. The serial-to-parallel converter is programmed to feed a first bit of the digital data to the first signal modulator to represent the first bit by modulating in the first frequency sub-band at a first power level at least as high as the first minimum power. The serial-to-parallel converter is also programmed to feed a second bit of the digital data to the second and third modulators to represent the second bit by coherently modulating in both the second and the third frequency sub-bands at a second power level below the first power level, whereby resulting signals applied in the second and third frequency sub-bands may be combined by the receiving modem to retrieve the second bit. The first and second minimum number of bits are both equal to one in the absence of some other specified constraint.

According another embodiment, the invention provides a frequency division multiplexor transmitting data from a data source over a channel. The multiplexor has a signal modulator with an input and first, second, and third outputs, each output transmitting data in a respective one of first, second, and third frequency bands. A channel response detector connected to the channel detects a transfer characteristic of the channel, the transfer characteristic including a noise power level and an attenuation of the channel. A controller connected to the signal modulator controls an allocation of first and second blocks of data from the data source for transmission in the first, second, and third frequency bands. The controller is programmed to transmit the first block of data in the first frequency band and transmit the second block redundantly in each of the second and third frequency bands at a first power level when the channel transfer characteristic is such that a power level required to transmit the second block, at a specified bit error rate, in the second frequency band alone is a first power level. However, when the channel transfer characteristic is such that a power level required to transmit the second block, at the specified bit error rate, in the second frequency band alone at a second power level, the second power level being higher than the first power level, the controller transmits the second block in the second frequency band alone.

According still another embodiment, the invention provides a modem with a frequency-division modulator and a controller. The modulator transmits input data in separate frequency channels. The controller has a memory that stores a power spectral density (PSD) mask specifying the maximum power levels permitted for each of the frequency channels. The controller's memory also stores an aggregate power limit specifying a total permitted power for all of the signals in all of the channels. The controller is programmed to measure and store in the memory the channel transfer characteristic of a communications channel through which the input data is to be transmitted. The controller is also programmed to transmit respective unique portions of the input data in of the frequency channels based on the stored aggregate power limit, the PSD mask, when the measured transfer characteristic is a first transfer characteristic. The controller is programmed to transmit a same portion of the data in at least two of the frequency channels responsively to the stored aggregate power limit, the PSD mask, when the measured transfer characteristic is a different transfer characteristic.

According still another embodiment, the invention provides a method for use in a data modulator for allocating bits to data channel frequencies. The method includes the following steps. (1) storing mask power data representing a respective maximum power level for each of the data channel frequencies; (2) storing aggregate power data representing a total amount of signal power to be applied in all of the channel frequencies; (3) allocating bits on a per frequency basis, such that bits are successively allocated until the respective maximum power level is at least substantially reached for each of the channel frequencies and such that each of the bits is allocated to a single respective one of the channel frequencies; and (4) when the aggregate power level is not substantially reached in the step of allocating, further allocating bits to multiples of the channel frequencies for transmission at reduced power rates per channel frequency, to permit further bits to be allocated, until one of the aggregate power limit is substantially reached and the respective maximum power level is reached for each of the data channel frequencies.

According still another embodiment, the invention provides an apparatus that allocates bits for data transmission via a multiple discrete frequencies. The apparatus has tone ordering circuitry, gain scaling circuitry and an inverse discrete Fourier transform modulator. The circuitry in combination allocates initial bits to frequencies on a per frequency basis, such that the initial bits are successively allocated until a maximum power level for each frequency

is at least substantially reached, each of the initial bits being unique to a given frequency. The circuitry also calculates a stored total power level for the initial bits allocated to a plurality of transmit frequencies, and if the stored total power level is not exceeded, allocate further bits to frequencies for which no initial bits are allocated, such that each of the further bits is redundantly allocated to more than one of the frequencies.

According another embodiment, the invention provides a frequency-division multiplex (FDM) transmission system for a channel having multiple subchannels, each of the subchannels being susceptible to cross-talk interference from another of the subchannels. The system comprises a transmitting modem with a programmable FDM modulator connected to modulate first and second frequency carriers, representing an input data stream, in each of first and second subchannels of the channel. Also, the system includes a receiving modem connected to the channel and a modulator programmed to modulate the first and second frequency carriers coherently to represent a first subportion of the data stream in the first and second frequency bands to form first and second signals in the first subchannel. The modulator is programmed to modulate the first and second frequency carriers coherently to represent a second subportion of the data stream in the first and second frequency bands to form third and fourth signals in the second subchannel. The receiving modem has a demodulator configured to combine coherently the first and second signals. The modulator is also programmed to form the third and fourth signals such that when the demodulator combines coherently the first and second signals, cross-talk interference in the first subchannel, caused by concurrent transmission of the third and fourth signals in the second channel, is diminished in a combined signal resulting therefrom.

According to still another embodiment, the invention provides a method for reducing near end cross talk. The method performs the following steps. (1) forming first and second signals in respective first and second tones redundantly representing first data to form a first multi-tone signal such that the first and second signals are weighted by a first vector of an orthogonal set of codes; (2) applying the first multi-tone signal to a first interfering channel; (3) forming third and fourth signals in the respective first and second tones redundantly representing second data to form a second multi-tone signal such that the third and fourth signals are weighted by a second vector of an orthogonal set of codes; (4) applying the second multi-tone signal to a second interfering channel; and (5) combining the first and second multitone signals such that a distortion in the first data caused by near end cross talk in first interfering channel is diminished.

According to still another embodiment, the invention provides a frequency-division multiplex (FDM) transmission system for transmitting an input data stream through a channel. The system has a transmitting modem with a programmable FDM modulator connected to modulate first and second frequency carriers, representing an input data stream, in the channel. The system also uses a receiving modem connected to the channel. A modulator is programmed to modulate the first and second frequency carriers coherently to represent a first subportion of the data stream in the first and second frequency bands to form first and second signals. The receiving modem has a demodulator configured to combine coherently the first and second signals to extract the first subportion such that an incoherent distortion of the first and second symbols in the first channel is, on average, reduced in the extracted first subportion.

According to still another embodiment, the invention provides a method for increasing a data rate in a communication channel subject to a power spectral density mask. The method follows these steps: (1) detecting a transfer characteristic indicating a required minimum power of a respective carrier modulated to transmit one bit in each of a plurality of multitone subchannels of the channel; (2) supplying a data stream to a modulator; (3) modulating a first set of respective carriers to represent respective unique portions of the data stream in at least a subset of those of the multitone subchannels for which, in the step of detecting indicates the minimum power falls below a power limit imposed by the power spectral density mask; (4) modulating a second set of respective carriers to represent redundantly at least one portion of the data stream in at least a subset of those of the multitone subchannels for which the step of detecting indicates the minimum power exceeds a power limit imposed by the power spectral density mask; (5) receiving the at least first and second symbols at a receiving end of the communication channel; (6) combining the at least first and second symbols received at the receiving end in such a way as to increase a signal power of the at least first and second symbols and, on average, reduce incoherent distortion of the at least first and second symbols; (6) reconstructing the same portion of the data stream at the receiving end from a combination of the at least first and second symbols, resulting from the step of combining.

According still another embodiment, the invention provides a communications system for communicating data in a channel having multiple subchannels. The system has a modulator with an output for each of the subchannels. It also employs a demodulator with an input for each of the subchannels. The modulator has an input connected to receive data from a data source. The modulator is programmed to modulate separate sets of carriers in each of the subchannels to represent respective portions of the data. The modulator is also programmed to modulate n separate frequency (resulting from a modulation of the modulator being output by the modulator) carriers coherently in each of the subchannels to represent a one of the respective portions of the data. Each of the n modulated signals, upon being received at the demodulator, includes an incoherent component resulting from attenuation and/or noise in the channel, a first coherent component resulting from near-end cross talk from the n modulated signals in the subchannels other than the each, and a second coherent component output which is the original n modulated signals output by the modulator. The modulator modulates the n separate frequency carriers such that when the demodulator demodulates the n modulated signals, upon being received at the demodulator, by linearly combining the received n modulated signals, in a signal resulting from the linearly combining, the incoherent component and the first coherent component are, on average, suppressed and the second coherent component is, on average, amplified.

According still another embodiment, the invention provides a transmitting modem receiving digital data from a data source, modulating carriers to represent the digital data, and applying a resulting modulated signal to a channel connectable to a receiving modem. The transmitting modem has first, second, and third signal modulators, each with an input. The modem also has a signal combiner with a combined output connected to the channel and a serial-to-parallel converter connected to the data source and to each of the first and second signal modulator inputs such that the digital data from the data source is converted to multiple parallel streams applied respectively to the first and second

signal modulators. Each of the first and second signal modulators has a respective output connected to the signal combiner such that a sum of output signals of the first and second signal modulators is applied to the channel. The serial-to-parallel converter is programmed to feed a bit of the digital data to the first and second modulators to represent the second bit by coherently modulating in both the first and second frequency sub-bands, whereby resulting signals applied in the first and second frequency sub-bands may be coherently linearly combined by the receiving modem to retrieve the bit and such that incoherent components and coherent but at least partially orthogonal components of the resulting signals are attenuated and coherent component of a modulated signal applied by the first and second modulators is amplified.

According to still another embodiment, the invention provides a method for transmitting data through a channel subject to a power spectral density mask limit and an aggregate power constraint. According to the method, a frequency-dependent transmission characteristic of the channel is detected. First and second sub-bands of an aggregate transmission band are defined responsively to a result of the step of detecting, the aggregate power constraint, and the power spectral density mask limit. A first modulated signal is generated, the signal having a first power dynamic range permitted by the power spectral density mask limit, the first modulated signal representing the first portion of the data. A second modulated signal is generated, the second signal having a second power dynamic range permitted by the power spectral density mask limit, the second modulated signal representing the second portion of the data.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawing,

FIG. **1** shows an arbitrary transform characteristic of an arbitrary channel with multitone channels, a power spectral density mask limit, and a minimum power required to transmit a single bit, assuming a specified error and symbol rates, superimposed thereon;

FIG. **2** shows modems in communication over one or more twisted wire pairs for purposes of describing an embodiment of the invention;

FIG. **3** shows a general diagram of elements of a communication system for purposes of describing an embodiment of the invention;

FIG. **4** shows a digital modulator and demodulator connected by a communication channel for a multitone QAM system for purposes of describing an embodiment of the invention;

FIGS. **5** & **6** show a flow diagram for purposes of describing a control method and apparatus controlling the embodiment of FIG. **4**.

FIG. **7** shows a conceptual rendering of how signals in separate channels may interfere and how the resulting distortion may be canceled according to an embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. **1** and **2**, a transmitting modem **31** is connected to a receiving modem **32** by a cable **33** having four twisted pairs of conductors. In long loop systems where cable **3** is of length of the order 18,000 feet or more, high signal attenuation at higher frequencies (greater than 500 kHz) is usually observed. This characteristic of cable **33** is represented graphically by curve A in FIG. **1**.

For convenience of description, the details of digital modulator **14** and digital demodulator **16** are described in terms of a QAM multitone system, although the invention is applicable to other kinds of multi-carrier and multi-channel signaling as will be understood by those skilled in the art in light of the teachings disclosed herein.

Referring now also to FIG. **3**, Modems **31** and **32** contain a source encoder **11**, a channel decoder **12**, a digital modulator **14**, to take in and transmit data from a data source **11**. Modems **31** and **32** also contain a digital demodulator **16**, a channel decoder **17**, and a source decoder **18** to receive the data and supply it to a data sink **19**.

As will be recognized by those skilled in the art, source encoder **12** compresses data from data source **11** and applies the result to channel decoder **13** which error correction/detection data and applies the result to digital modulator **14**. Digital modulator acts as the interface with the communication channel by modulating the data to generate a signal that can be applied to the communication channel **15**. Digital demodulator **16** constructs a data stream from the modulated signal and applies it to channel decoder **17**. Channel decoder **17** corrects errors in the data stream and applies the corrected data to source decoder **18** which decompresses the data and outputs the decompressed data to data sink **19**.

Referring to FIG. **4**, In a QAM multitone modulation, the spectrum is broken into multiple sub-bands or QAM channels. Digital modulator **14** generates N QAM signal tones, one for each QAM channel. Each i^{th} QAM channel carries k_i bits of data. A serial-to-parallel buffer **41** segments a serial stream of digital data into N frames, each having allocated to it k_i bits of data. These are applied to respective inputs of a multi-carrier modulator **42** which generates a QAM tone for each channel. Multi-carrier modulator generates N QAM tones, one for each channel, at the same symbol rate but with a respective constellation for each channel. That is, the i^{th} QAM channel carries an 2^{ki}-ary QAM tone, a tone with 2^{ki} signal points. Multi-carrier modulator modulates N subcarriers by corresponding symbols to generate the N QAM signal tones using an inverse digital Fourier transform. The allocation of bits in serial-to-parallel buffer **41** is discussed in detail below.

A parallel-to-serial converter **43** adds a cyclic prefix (one known method of preventing intersymbol interference) and sums the separate modulated data and passes the resulting data stream through an D/A converter **44** yielding a single analog signal stream. After the analog signal reaches receiving modem **32**, the opposite operation occurs in A/D converter **46**, serial-to-parallel converter **47**, and multicarrier demodulator **48** and detector **49**. Multicarrier demodulator **48** strips the modulating signal from the carrier, that is, it converts the QAM tone data into data representing the original modulating symbols. Detector 49 maps the resulting symbols into a set of bits either by quantizing or soft-decision quantization. These symbols are then queued up in a serial data stream by parallel to serial converter 50.

Referring again to FIG. **1**, the allocation of bits in serial-to-parallel buffer 41 is performed according to an algorithm which is now described. In FIG. **1**, the channel transform characteristic (an attenuation/noise floor) A, in the range of sub-band b**1**, is such that at least one bit can be represented by a QAM-encoded tone signal transmitted in that sub-band. The same is true for sub-band b**2**. However, the amount of power available in sub-bands b**3** and b**4** are such that a QAM tone generated within the power ceiling overlying those

bands would not meet the BER and symbol rate required (the minimum power to represent 1 bit being represented by curve C).

If, in the process of assigning bits to the available frequency sub-bands or "bins", the total aggregate power limit is not exceeded, then there may be otherwise "wasted" power available due to the inability to put signals in frequency sub-bands for which the spectral density mask is too close to the attenuation/noise floor A for a single bit to be transmitted but for which there is still available "room" for signal power. Such noisy and/or highly attenuated sub-bands can occur for example in long-run twisted pair conductors. Unutilized but otherwise available power could be put in the frequency sub-bands such as b**3** and b**4** for which the noise-floor (curve A) is too high to permit a single bit to be properly represented. According to the invention, digital modulator **14** replicates ("spreads") a k-bit symbol over multiple adjacent bands with correspondingly less energy in each band. At the receiving end, detector **49** coherently recombines ("despreads") the redundant symbols in the noisy/attenuated sub-bands. In recombining the symbols, the symbols are simply arithmetically added. Because the noise is incoherent while the signal is coherent, the noise tends to be averaged out while the signal is reinforced by the addition process.

In view of the above process of spreading and despreading certain channels according to the allocation scheme defined above, detector **49** is capable not only of detecting signal transmitted conventionally in one frequency bin, but, also of selectively summing the blocks previously spread and transmitted over the noisy/attenuated sub-bands. Of course this is done under programmable control so that, depending on the results of the initial channel SNR estimation procedure, command signals are sent to both the transmitting and receiving modems to appropriately perform the spreading and despreading processes.

In a practical implementation of the bin-filling procedure described by Bingham (see Background section), additional constraints such as minimum and maximum number of bits per bin, a power spectrum mask, and a desired set of bit rates may also be considered. Within these constraints and those of the power spectral density mask and the aggregate power limit discussed above, the bin-filling procedure would be followed until the process is halted by any of these limits. Then a second process of allocation is performed to assign bits to frequency channels that are unallocated due to their not having sufficient power-per-channel to transmit the minimum number of bits. The second procedure determines if these channels can be used within the constraints imposed by the other limits. Thus, a first step applies a first algorithm to allocate bits to each channel within the constraints of aggregate power, maximum power per channel (PSD mask), and the maximum and minimum number of bits per channel. Note that any algorithm that allocates one constellation to each frequency bin would constitute an appropriate first step. A second algorithm is applied to allocate identical blocks of data to multiple channels through spreading as discussed above. The second algorithm would allocate bits to channels if sufficient power margin is available in multiple channels in the aggregate to transmit an additional minimum-sized block of data without exceeding the aggregate power limit. However, it may turn out that transmission of some blocks through spreading is cheaper in terms of power use than transmitting those as allocated during the first allocation procedure. In that case, an approach that employed spread and unspread signaling in an approach that allocated each bit to the channel or channels associated with the least marginal power consumption. would be an alternative approach that might lead to more channels being used for spreading than for the two-step approach discussed in detail below. Generally, the most efficient utilization of a channel is to allocate data to channels with the highest SNR, which is the whole idea behind the water-pouring analogy, so the latter approach is not preferred. However, there may be channels with certain kinds of transform characteristics for which such an approach would produce improved performance.

Referring to FIG. **5**, a practical bit-allocating algorithm is proposed in a US Patent Application entitled Method and Apparatus for Allocating Data for Transmission Via Discrete Multiple Tones-Sonalkar, et. al. According to this procedure, bit allocation is performed with consideration to all practical constraints discussed above. In the method described in the above reference, the entirety of which is incorporated herein by reference, bits are allocated according to the requirements of an aggregate power constraint, a power-spectral density mask limit, and minimum and maximum bits per symbol (e.g, QAM tone).

According to an invention described by Sonalkar, et. al. in the application identified above, the following constraints are considered first: the maximum number of bits allowed in each tone or frequency bin for transmission and the maximum power to be transmitted in each bin (the power-spectral-density mask). Then, the aggregate power constraint (power budget) is applied in a second process. During the second step, if necessary, bits are removed according to a bit removal procedure that removes the bit from the channel, the removal of which results in the greatest decrease in aggregate power required. With this process, the fewest bits are removed because the bit that produces the highest marginal gain in power savings is selected for removal (deallocation).

In the first procedure, the maximum number of bits per bin is calculated first with consideration only to the power mask constraint and any minimum and maximum bits per bin (channel) constraints. First, in step S**21**, the channel's transform characteristic is calculated during an initialization period. Then, in step S**22**, the maximum number of bits that can be allocated to each bin is calculated. This computation is done from a relationship between the number of bits (b_k) to be transmitted in a bin and the power needed to transmit that many bits (b_k) in bin number k. For purposes of this calculation, the PSD mask-limited value for bin k serves as the power available for transmission in the channel corresponding to bin k.

At step S**23**, the total power requirement over all channels is calculated over all the transmit frequency bins. Then in step S**24**, the total power requirement is compared to the aggregate power limit. From the standpoint of the aggregate power limit, for example 100 milliwatts total maximum power, the bins may be considered to be overflowing at this point. If the total maximum power is not exceeded, then, the first procedure is completed and a second procedure where the spreading techniques apply, is implemented (See FIG. **5**). On the other hand, if the total power limit is exceeded, then the first procedure continues with a bit removal process, in step S**25** as follows.

The bit removal process is implemented to reduce the bit allocation so that the total power required for transmission meets the aggregate power limit. According to a preferred bit removal process, bits are removed sequentially, each bit being selected in turn as the bit, the removal of which, produces the greatest marginal gain in terms of recovered

power. The first bit removed then is the bit that cost the most power to transmit. After the bit is deallocated, the corresponding power saved is subtracted from the total power. If the total power constraint is still exceeded after removal of the bit, the next most power-consuming bit is removed. This process is followed iteratively until the power constraint is no longer exceeded. Once the aggregate power limit is met, the first procedure is completed and no second procedure follows.

Referring now also to FIG. **5**, in preparation for the second procedure, the first procedure sketched above is performed and it is confirmed that residual power remains. That is, that the difference between the aggregate power limit and the sum of the signal power over all frequencies subject to the other limits (minimum and maximum bits per channel and PSD mask limit) is greater than zero. Note that if the first procedure of FIG. **4** gets to the second phase of step S**25**, there will be no residual power and the procedure of FIG. **5** will not be performed.

The decibel sum of attenuation plus noise power, plotted as a function of frequency, may be perceived as a "terrain" on which the communication channel operates. A classic algorithm called "water filling" refers to continually budgeting signal power, which is the constrained resource, at the low points of this terrain first to achieve the optimum efficiency in terms of information per unit of power. One approach to multi-band assignment, therefore, is to continue this process by selecting the next four bands from a list of bands sorted with respect to the attenuation-plus-noise parameter or the power required to transmit a block of data. While this guarantees the most efficient use of the remaining spectrum under the set of constraints described above, such a procedure does not in general yield 4-tuples that are adjacent in frequency. This procedure is adopted in the process described next.

The second procedure begins at step S**2**. An index is set to 1 and a number of bins for spreading (the number of channels over which each block will be spread). This can be done as part of an optimization procedure or selected a priori. To limit the administrative and communication overhead associated with initialization and bit assignment (as well as the computational complexity to explore combinatorics of a large number of options), there is strong motivation to limit the number of grouping options to a single option. That is, either bits are assigned to individual bands as in the prior art, or where spreading is applied, a single sized m-tuple of frequency bands is allowed. (Choosing a larger value of m consumes frequency bandwidth more rapidly, choosing a smaller value limits the SNR deficit that can be overcome.) Empirical studies of actual telephone loop propagation characteristics indicates the payoff is greatest for making the number of bins, m, equal to 4 under this set of conditions.

Next, at step S**3**, an array is calculated containing the power required to transmit one bit for all bins that were not allocated in the procedure of FIG. **5**. The array indicates the bin by a frequency pointer (a label), the number of bits already assigned to that bin, and the power requirement to add another bit to that bin. Now, the power required to transmit b_k bits is given by:

$$E_k = (2^{b_k} - 1)\cdot\left(\frac{KN_k}{3g_kG_c}\right), \tag{1}$$

where:

b_k is the number of bits carried in frequency bin k, E_k is the power required in bin k to transmit the b_k bits, g_k/N_k is the measured gain to noise ratio in bin k, and G_c is the coding gain. K is given by:

$$K = \left[Q^{-1}\left(\frac{P_e}{N_e}\right)\right]^2, \tag{2}$$

where P_e is the error probability given by:

$$P_e = 4\left(1 - \frac{1}{\sqrt{2^{n_i}}}\right)Q\left[a\sqrt{\frac{2}{N_0}}\right], \tag{3}$$

the Q function is the partial integral of the normal distribution function given by:

$$Q(x) = \int_x^\infty \frac{1}{\sqrt{2\pi}}\cdot e\frac{-u^2}{2}\cdot du, \tag{4}$$

N_e is a number that assumes a value in the range of 2 to 4, in the preferred embodiment of the invention, N_e is equal to 3. Since the second procedure for allocating bits to the impaired channels (the channels for which the SNR ratio does not permit a bit to be transmitted without hitting the PSD mask limit) allocates one bit at a time, b_k can be set to 1 and equation (1) thus reduces to (also dividing by 4 to account for the spreading):

$$E_k = \left[\frac{1}{4}\right]\cdot\frac{KN_k}{3g_kG_c} \tag{5}$$

Thus in calculating the power bin array, the number of bits already allocated to each of the bins is taken into account in calculating the power requirement. So the power requirement calculation is a marginal power required to add another bit to the bin. In calculating the amount of power required, if the calculated power would exceed the PSD mask limit for that bin, a very large number is used for the energy requirement so that when the array is sorted in order of increasing power, these bins with low PSD limits end up at the bottom of the sorted list.

In step S**4**, the power bin array is sorted in ascending order of power requirement so that the element with an index of one corresponds to the bin with the lowest energy requirement. Once the array is sorted, the array is repopulated with the bins with power requirements below the large number (used to put bins for which an additional bit would exceed the PSD mask limit) and a bins-remaining-counter, indicating the number of bins to which a bit can still be assigned, is decremented to reflect the current number of bins now available.

In step S**7**, the bins-remaining counter is checked to see if m-1 remain. If insufficient bins remain to spread a bit, the procedure terminates.

In step S**5**, the residual power (difference between aggregate power requirement and the power required to transmit all assigned bits) is calculated from all assigned bins using equation (1). Next, in step **9**, the total power to transmit one bit in the adjacent m bins is calculated. Note that the m adjacent bins are adjacent in terms of the index value corresponding to the power sorting done in step S**4**, not the arrangement in terms of frequency.

After step S**9**, control proceeds to step S**10** where, if the total power required to transmit one bit spread across the m bins exceeds the residual power, the program terminates, otherwise control proceeds to step S**12**. At step S**12**, a bit is allocated to each of the m bins.

Once the procedure of FIG. 6 terminates, the array indicates the number of bits to transmit in each bin. Note that the procedure can, in principle, assign "spread bits" to bins that carry one or more entire bits by themselves.

Referring to FIG. 7, a system for a channel employing four twisted pairs will be described. Each pair of wires is an independent interfering channel. That is, a signal in one channel generates a corresponding signal in the other channels. In the four twisted pair system described here and shown in FIG. 7, a single block of data is spread across the same number of channels, in this case four. Four data blocks, possibly represented by, for example, a single QAM tone, are labeled A, B, C, and D. Each block is redundantly transmitted at four separate frequencies. However, instead of applying the signal tone directly to the channel, the transmitter weights the signals by respective elements of orthogonal, 4-element Walsh codes. The receiver de-weights the received signal at the receiving end and then despreads (sums) the de-weighted blocks to obtain the signal. The result of this is that the induced signal caused by interference is canceled out because the process of weighting each original signal by one code and de-weighting the induced signal in an adjacent channel by a different code, orthogonal to the first, causes the sums to cancel out. For example, signal B is weighted by a first code. The signal induced by signal B in adjacent channels, represented in FIG. 7 by the lower case letters, in this case "b", is also weighted by the first code. But when the signal in an adjacent channel, say channel **3** carrying signal C, arrives at the receiver, the signal C combined with an induced portion of B weighted by the first code is then deweighted by a second code. Thus, when signal C is despread (summed), the induced signal in each frequency channel cancels an induced signal in another frequency channel.

To use the invention for eliminating interference from other channels, it is not necessary to allocate bits to channels as described with reference to FIGS. 5 and 6. In fact, all data could be spread across multiple frequency channels.

Note that in a channel where signal spreading is to be used for reducing interference, one that includes multiple interfering sub-channels, it is desirable for communications to be set up with cognizance of how spreading is to be done on each of the sub-channels. That is, for example, the frequency bins in each twisted pair in a four-twisted pair bundle should all have the same bit assignments so that the interference will be canceled out as described above.

As a first level concept, the present invention relates to replicating (i.e. spreading) the spectral contents of a signal over multiple distinct parts of the physical frequency band to compensate for high attenuation and/or high noise in those parts of the communication channel frequency band that would otherwise not be usable due to noise and attenuation effects. Of course, if signal power could be increase arbitrarily, no portion of the spectrum would be unusable, however, practical considerations and standards, as discussed above, dictate otherwise. The effect of the replication is that signal-processing techniques can be used in the Receiver to recover information sent in the impaired parts of the frequency band, and, with the correct choice of parameters (i.e. degree of replication), the same level of performance (specifically bit error rate) as achieved in the unimpaired parts of the band can be achieved in portions of the band where attenuation and/or noise are high.

The consequence of this technique is a communication signal where the frequency-domain spreading (replication) is used selectively, such that not all spectral content has the same degree of redundancy, some having no redundancy as appropriate. This might be termed a hybrid modulation because of the mixed-mode, or non-uniform replication. The advantage clearly lies in the fact that spectrum is used efficiently with non-redundant transmission for those parts of the band where adequate signal-to-noise can be achieved, while spreading is applied to those parts of the band where transmission would otherwise be impossible. The added bandwidth incrementally consumed by spreading is therefore not wasteful since it exploits portions of the band that are otherwise unusable.

As mentioned the bit allocation process is not limited by the aggregate power constraint that applies, but by the second limit on the power in each band, the power spectral density mask. This occurs may occur in long lines and/or noisy environments. The mask prevents assigning any further bits to unoccupied bands because the attenuation and noise would require too much power in any of the remaining bands.

The proposed concept is to overcome the circumstance outlined above by repeating the same X, value in multiple positions in the input array to the IFFT. In this way, signals which individually do not have adequate signal/noise ratio to achieve the desired bit error rate are simply summed at the receiver to achieve the requisite SNR. As an example, summing two copies of the same QAM vector, each contaminated with the same level of noise power but with the respective noise uncorrelated, results in 6 dB signal enhancement versus 3 dB, noise growth, for a net improvement of 3 dB. In general the net enhancement is increased 3 dB, each time the number of frequency bands is doubled.

A further constraint on the allocation process described above would be to limit the 4-tuples selected to be adjacent in frequency, that is, the 4-tuples (. . . in this example, m-tuples in general) would form a sequential series of frequency bands. This would require starting at bands with indices that are integral multiples of 4. These constraints, while compromising ideal allocation objectives, would tremendously increase the likelihood that neighboring interfering channels would have 4-tuples assigned to the same set of frequency bands. If neighboring channels are synchronized, and have replicated vectors weighted by orthogonal, 4-element Walsh codes, the result is that the mutual interference among this group of 4 wire pairs can be zero in any of the 4-band spread channels. Because the services provided by such modems is expected to be ultimately interference—limited if the service becomes popular and widespread, this capability to avoid/mitigate mutual interference among cooperating neighbors is significant. Even without orthogonality, the spreading provides a significant signal processing gain with respect to uncorrelated interference. The orthogonality feature adds a further enhancement.

Although according to the embodiments described above, power is distributed equally to the bins across which a single block is transmitted, it is clear from the description that other possibilities exist. For example, the m bins could be assigned power on a pro rata basis according to the noise-power/gain ratio corresponding to each bin. Thus, the bin corresponding to the lowest noise-power/gain ratio could carry the greatest share of the power. Bins could also be allocated different power levels according to the power margin available below the PSD mask limit.

Also, although according to the embodiments described above, a number of bins for spreading is established before allocation of data to the bins, it is possible in view of the teachings of the present specification, to spread different blocks of data over different numbers of bins. For example, one block consisting of one bit could be spread over 2 blocks

and second bit, perhaps in a more impaired (by noise and/or attenuation) portion of the spectrum, spread over a larger number of bins. This could be done iteratively and the number of bins increased until all available spectrum were fully exploited (within the external and practical constraints).

Also, although according to the above embodiments, spreading is only done when the noise-attenuation floor makes transmission of a single bit impossible for any channels remaining, other possibilities exist in view of the teachings of the present specification. For example, spreading can be done in certain frequency channels which otherwise might possibly be used to carry a single bit on their own.

The following applications, filed concurrently herewith, are hereby incorporated by reference:

1. A Hybrid Fiber Twisted-pair Local Loop Network Service Architecture (Gerszberg 41-3-13);
2. Dynamic Bandwidth Allocation for use in the Hybrid Fiber Twisted-pair Local Loop Network Service Architecture (Gerszberg 42-4-14);
3. The VideoPhone (Gerszberg 43-9-2);
4. VideoPhone Privacy Activator (Gerszberg 44-10-3);
5. VideoPhone Form Factor (Gerszberg 45-11-4);
6. VideoPhone Centrally Controlled User Interface With User Selectable Options (Gerszberg 46-12-5);
7. VideoPhone User Interface Having Multiple Menu Hierarchies (Gerszberg 47-13-6);
8. VideoPhone Blocker (Gerszberg 79-38-26);
9. VideoPhone Inter-com For Extension Phones (Gerszberg 48-14-7);
10. Advertising Screen Saver (53-17);
11. VideoPhone FlexiView Advertising (Gerszberg 49-15-8);
12. VideoPhone Multimedia Announcement Answering Machine (Gerszberg 73-32-20);
13. VideoPhone Multimedia Announcement Message Toolkit (Gerszberg 74-33-21);
14. VideoPhone Multimedia Video Message Reception (Gerszberg 75-34-22);
15. VideoPhone Multimedia Interactive Corporate Menu Answering Machine Announcement (Gerszberg 76-35-23);
16. VideoPhone Multimedia Interactive On-Hold Information Menus (Gerszberg 77-36-24);
17. VideoPhone Advertisement When Calling Video Non-enabled VideoPhone Users (Gerszberg 78-37-25);
18. Motion Detection Advertising (Gerszberg 54-18-10);
19. Interactive Commercials (Gerszberg 55-19);
20. VideoPhone Electronic Catalogue Service (Gerszberg 50-16-9);
21. A Facilities Management Platform For Hybrid Fiber Twisted-pair Local Loop Network, Service Architecture (Barzegar 18-56-17);
22. Multiple Service Access on Single Twisted-pair (Barzegar (16-51-15);
23. Life Line Support for Multiple Service Access on Single Twisted-pair (Barzegar 17-52-16);
24. A Network Server Platform (NSP) For a Hybrid Fiber Twisted-pair (HFTP) Local Loop Network Service Architecture (Gerszberg 57-4-2-2-4);
25. A Communication Server Apparatus For Interactive Commercial Service (Gerszberg 58-20-11);
26. NSP Multicast, PPV Server (Gerszberg 59-21-12);
27. NSP Internet, JAVA Server and VideoPhone Application Server (Gerszberg 60-5-3-22-18);
28. NSP WAN Interconnectivity Services for Corporate Telecommuters (Gerszberg 71-9-7-4-21-6);
29. NSP Telephone Directory White-Yellow Page Services (Gerszberg 61-6-4-23-19);
30. NSP Integrated Billing System For NSP services and Telephone services (Gerszberg 62-7-5-24-20);
31. Network Server Platform/Facility Management Platform Caching Server (Gerszberg 63-8-6-3-5);
32. An Integrated Services Director (ISD) For HFTP Local Loop Network Service Architecture (Gerszberg 72-36-22-12);
33. ISD and VideoPhone Customer Premise Network (Gerszberg 64-25-34-13-5);
34. ISD Wireless Network (Gerszberg 65-26-35-14-6);
35. ISD Controlled Set-Top Box (Gerszberg 66-27-15-7);
36. Integrated Remote Control and Phone (Gerszberg 67-28-16-8);
37. Integrated Remote Control and Phone User Interface (Gerszberg 68-29-17-9);
38. Integrated Remote Control and Phone Form Factor (Gerszberg 69-30-18-10);
39. VideoPhone Mail Machine (Attorney Docket No. 3493.73170);
40. Restaurant Ordering Via VideoPhone (Attorney Docket No. 3493.73171);
41. Ticket Ordering Via VideoPhone (Attorney Docket No. 3493.73712);
42. Multi-Channel Parallel/Serial Concatenated Convolutional Codes And Trellis Coded Modulation Encode/Decoder (Gelblum 4-3);
43. Spread Spectrum Bit Allocation Algorithm (Shively 19-2);
44. Digital Channelizer With Arbitrary Output Frequency (Helms 5-3);
45. Method And Apparatus For Allocating Data Via Discrete Multiple Tones (filed 12/22/97, Attorney Docket No. 3493.20096—Sankaranarayanan 1-1);
46. Method And Apparatus For Reducing Near-End Cross Talk In Discrete Multi-Tone Modulators/Demodulators (filed Dec. 22, 1997, Attorney Docket No. 3493.37219—Helms 4-32-18).

What is claimed is:

1. A method for use in a data modulator for allocating bits to data channel frequencies comprising the steps of:

storing mask power level data representing a respective maximum power level for each of said data channel frequencies;

storing aggregate power level representing a total amount of signal power to be applied in all of said data channel frequencies;

allocating bits, such that bits are allocated up to said respective maximum power level for each of said data channel frequencies and such that each of said bits is allocated to a single respective one of said data channel frequencies; and

when said aggregate power level is not substantially reached in said step of allocating, further allocating bits to multiples of said data channel frequencies for transmission at reduced power rates per channel frequency, to permit further bits to be allocated, until an aggregate power limit is substantially reached and said respective maximum power level is reached.

2. A method as in claim **1** wherein said step of allocating bits is responsive to a channel transform characteristic sensitive to a noise power level of the channel and an attenuation of said channel and includes allocating bits to each data channel frequency by allocating bits to the data channel frequency having the lowest marginal power requirement to transmit an additional bit.

3. A method as in claim **1** wherein said step of further allocating includes selecting a data channel frequency from among a set of frequency channels for which no data allocated in said step of allocating.

4. A method as in claim **3**, wherein said step of further allocating includes selecting a data channel frequency from among said set based on a lowest marginal power requirement for transmitting a further bit.

5. A method as in claim **1**, wherein said step of allocating includes allocating according to a minimum number of bits per data channel frequency.

6. A method as in claim **1**, wherein said step of allocating includes storing an array of length equal to a number of frequency bins, the value of each element being a maximum number of bits to be transmitted.

7. A method as in claim **1**, wherein said step of further allocating includes storing an array of length equal to a number of frequency bins remaining unallocated in said step of allocating, the value of each element being an amount of power required to transmit a minimum number of bits in a frequency corresponding to a respective one of said frequency bins remaining.

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US006625219B1

(12) **United States Patent**
Stopler

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(45) **Date of Patent: Sep. 23, 2003**

(54) **METHOD AND APPARATUS FOR ENCODING/FRAMING FOR MODULATED SIGNALS OVER IMPULSIVE CHANNELS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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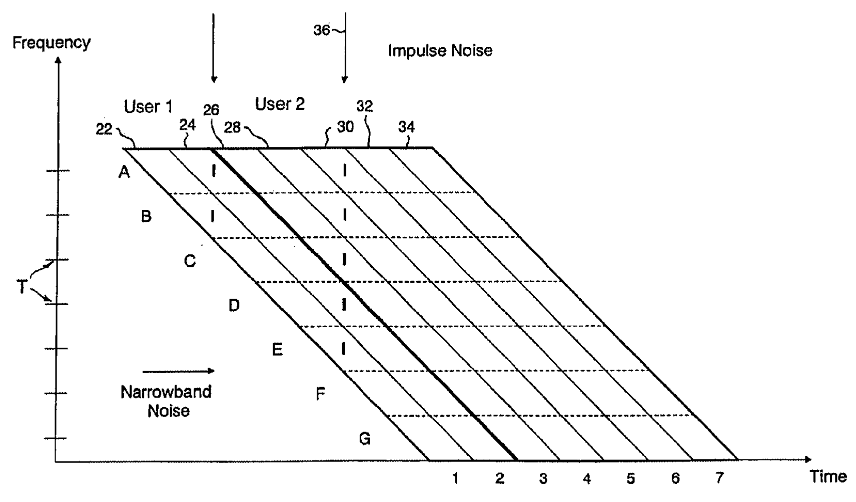
(57) **ABSTRACT**

An encoding/framing scheme for multitone modulation over impulsive channels which allows efficient operation in multipoint to point channels which are affected by ingress (narrowband noise) and impulsive (burst) interference. The coding is achieved using a concatenated approach, with the inner code being Trellis Coded Modulation (TCM), using, for example, convolutional coding, and the outer code being a Reed Solomon (RS) code. Two dimensional interleaving is performed, with one dimension being time, and the other dimension being frequency (tones or sub-channels). The TCM coding provided by the present invention is quite effective in dealing with impulse noise effects. The interleaving may be applied in two levels. According to one embodiment, user data is RS encoded, and a portion of the RS encoded data is interleaved and filled along columns for transmission using a multitone transmission system. The remaining portion of the RS encoded user data is then TCM encoded, interleaved and effectively filled along rows for subsequent transmission. In another embodiment, a portion of the user data is RS encoded, interleaved and filled along columns for transmission, while the remaining portion of the user data is instead TCM encoded, interleaved and effectively filled along rows for subsequent transmission. A diagonalization scheme is also used to provide immunity against impulse noise, while at the same time allowing for a simple method of utilizing tones of different loading. According to the diagonalization principle, data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. In this way, a code having lower redundancy can be used since the amount of corruption expected in one user's data packet will be reduced.

42 Claims, 6 Drawing Sheets



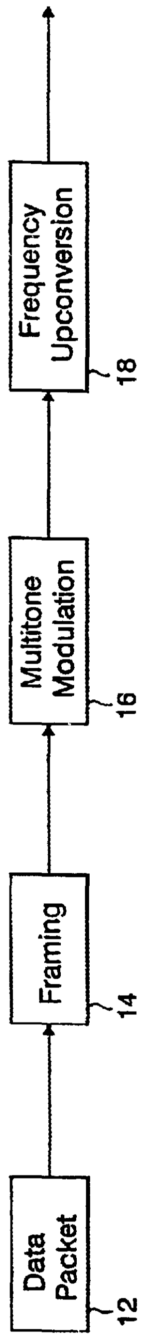


FIG. 1
PRIOR ART

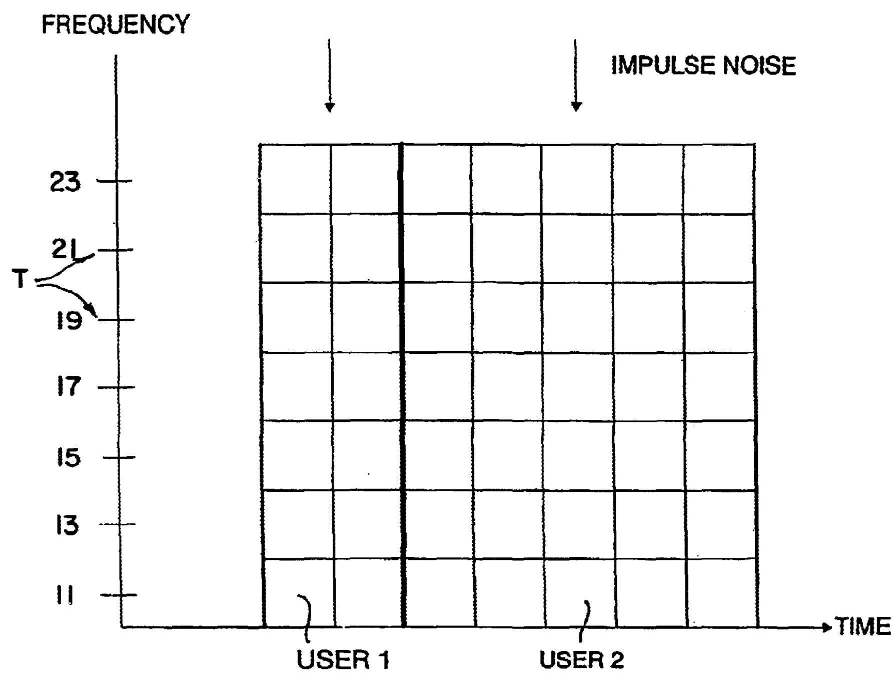


FIG. 2
PRIOR ART

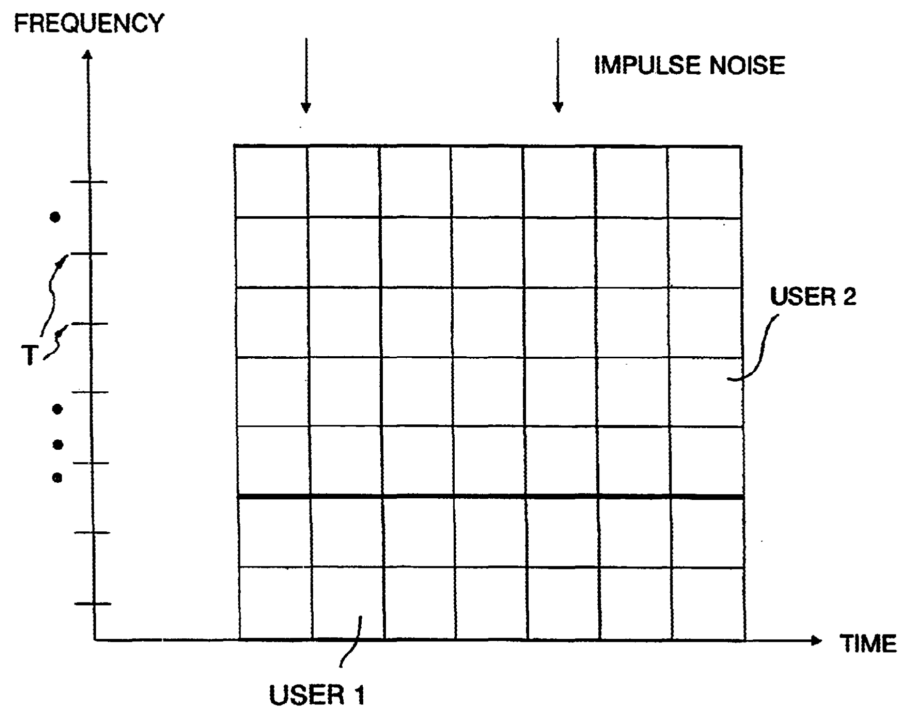


FIG. 3A
PRIOR ART

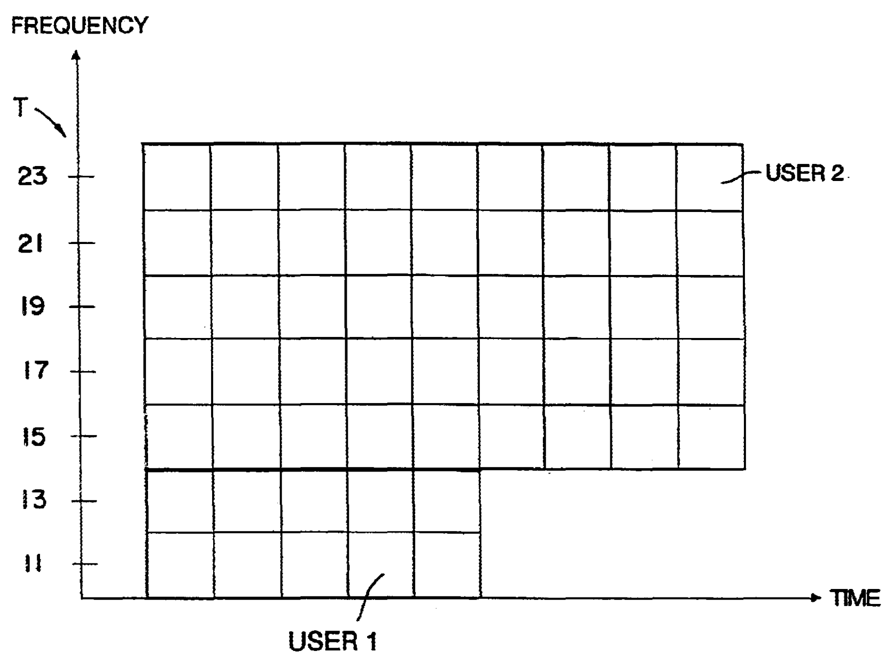


FIG. 3B
PRIOR ART

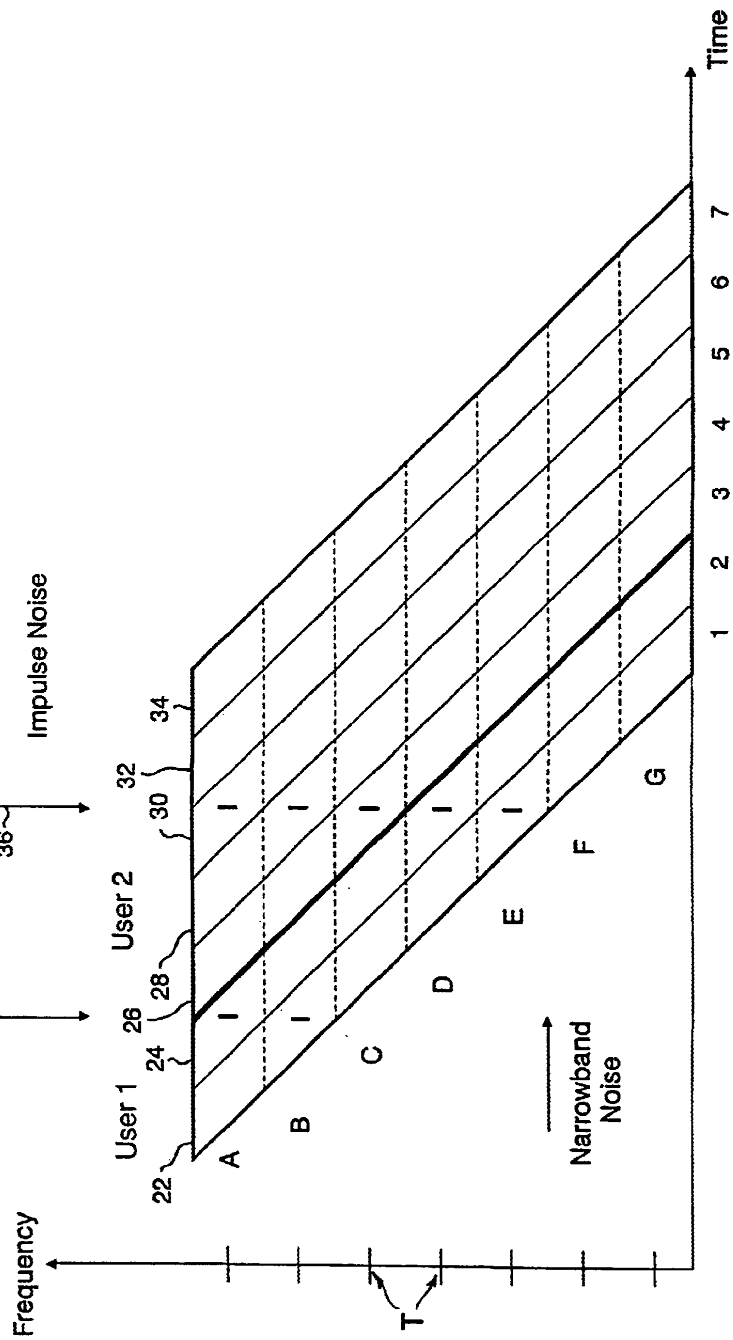

Impulse Noise
36
User 1
User 2
22
24
26
28
30
32
34
A
B
C
D
E
F
G
Narrowband Noise
Frequency
Time
T
1
2
3
4
5
6
7

FIG. 4

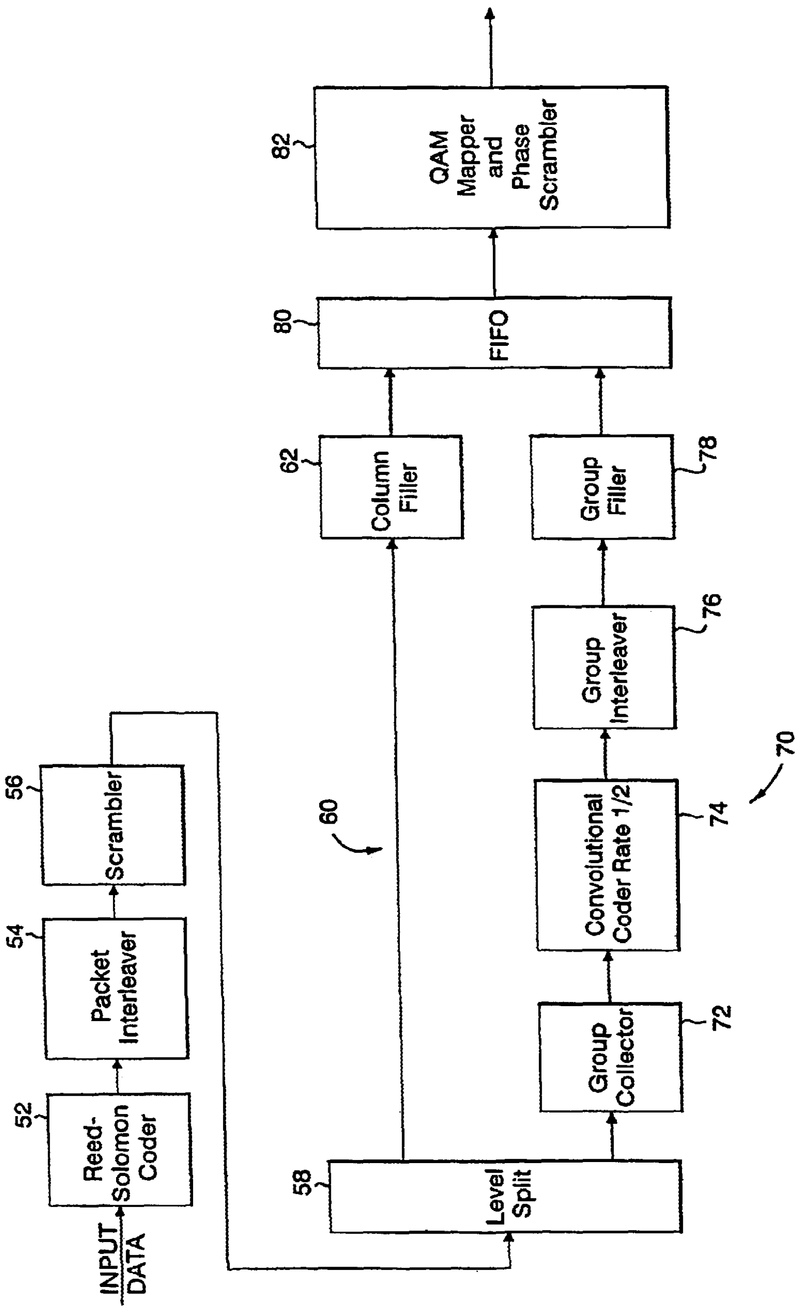

INPUT DATA
52
Reed-Solomon Coder
54
Packet Interleaver
56
Scrambler
58
Level Split
60
62
Column Filler
70
72
Group Collector
74
Convolutional Coder Rate 1/2
76
Group Interleaver
78
Group Filler
80
FIFO
82
QAM Mapper and Phase Scrambler

FIG. 5

METHOD AND APPARATUS FOR ENCODING/FRAMING FOR MODULATED SIGNALS OVER IMPULSIVE CHANNELS

FIELD OF THE INVENTION

The present invention generally relates to the field of data communications and processing. Specifically, the present invention relates to a method and apparatus for encoding/framing a data stream of multitone modulated signals to improve impulse burst immunity.

BACKGROUND OF THE INVENTION

Digital data communications systems are commonly used to transmit and/or receive data between remote transmitting and receiving locations. A central facet of any data communications system is the reliability and integrity of the data which is being communicated. Ideally, the data which is being transmitted from the transmitting location should be identical to the data which is being received at the receiving location. Practically however, the data to the data which is being received at the receiving location. Practically however, the data which is received at the receiving location has oftentimes been corrupted with respect to the original data that was transmitted from the transmitting location. Such data communication errors may be attributed in part to one or more of the transmission equipment, the transmission medium or the receiving equipment. With respect to the transmission medium, these types of data errors are usually attributed to the less than ideal conditions associated with the particular transmission medium. An example of such a communication medium or channel is the hybrid fiber coaxial cable television network, HFC CATV.

In certain channels, such as the HFC channel, errors may be caused by noise or other interference. One type of noise is ingress or narrowband interference which typically occurs at a fixed frequency and lasts for a long time. Another type of noise is impulse or burst interference which typically occurs at unexpected times, lasts for a short period of time (e.g., several microseconds), and corrupts all tones or bands.

Multitone modulation is a signal transmission scheme which uses a number of narrow-band carriers positioned at different frequencies, all transmitting simultaneously in parallel. Each narrow band carries a fraction of the total information being transmitted. The discrete bands or subchannels are independently modulated, and each have a carrier frequency at the center frequency of the particular band.

One type of multitone transmission scheme is discrete multitone, often referred to as DMT. In DMT, a 1.1 MHz channel is broken down into 256 sub-channels or bands, each of which is 4 KHz. Each of the sub-channels has its own carrier frequency, and the signal to noise ratio for each of the sub-channels is monitored by the DMT system to determine how many bits per signal may be carried in each of the sub-channels. Each of the sub-channels transmits a number of information bits in a single symbol or signal period. The number of bits per signal (or symbol) in a sub-channel is typically referred to as the "loading" of the sub-channel. The DMT system dynamically adjusts the loading of each of the sub-channels in accordance with the noise characteristics of the sub-channel. Particularly noisy sub-channels may sometimes not be used altogether.

DMT typically has long symbol periods of 250 microseconds. As a result, DMT exhibits fairly good immunity with respect to time domain events, since the effect of a time domain event will be averaged out over the relatively long symbol period. In this way, impulse noise has less of an effect on DMT transmissions. Although the effect is reduced, there is nevertheless, still an adverse effect due to impulse noise. With respect to narrowband interference, this type of noise is typically stable and can be compensated for by adjusting the loading of the particular, affected sub-channels.

Variable Constellation Multitone (VCMT) modulation is a transmission scheme specifically designed to effectively combat the high ingress and burst impairments in cable TV channels, and also to maximize the throughput capacity of such channels. VCMT uses variable bit loading per tone, along with coding and interleaving. The tones are independently modulated from QPSK (quadrature phase shift keying) to 256-QAM (quadrature amplitude modulation), depending on the noise measured for each tone. The SNR (signal to noise ratio) across the channel is monitored for each tone, and the headend receiver accordingly instructs the upstream transmitter in the cable modem to modify the QAM constellation for each tone to maintain a desired BER (bit error rate).

VCMT also utilizes spectral shaping to reduce the frequency sidelobes of the tones, as compared with conventional multitone modulation, in order to reduce the effect of narrowband interference to only those affected tones. As with all multitone modulation schemes, VCMT utilizes long symbol periods to average the effect of burst and impulse noise. Interleaving the data over time and frequency may also be used to minimize the number of impaired tones for each user.

The VCMT nominal configuration is designed for a bandwidth of 1.6 MHz. However, the VCMT configuration may be adapted for any particular bandwidth through proper modification of the system parameters. In the case of the nominal configuration, VCMT uses the following parameters:

RF Bandwidth:	1.6 MHz.
Number of tones:	36
Modulation:	QPSK to 256-QAM (per tone)
Inter-tone spacing:	43.75 KHz.
Signaling rate:	40 kbaud (per tone)
Data rate:	Variable, depending on tone modulation
Symbol shaping:	Modified square-root-raised-cosine, roll-off
0.09	
Symbol duration:	10 symbol periods (250 microseconds)

Code Division Multiple Access (CDMA) modulation is a multi-user access transmission scheme in which different users overlap both in frequency and in time. This is in contrast to Frequency Division Multiple Access (FDMA) in which users overlap in time, but are assigned unique frequencies, and Time Division Multiple Access (TDMA) in which users overlap in frequency, but are assigned unique timeslots. According to CDMA, each user is assigned a unique code sequence that allows the user to spread its information over the entire channel bandwidth, as opposed to particular sub-channel(s) in FDMA. Thus, signals from all users are transmitted over the entire channel. To separate out the signals for a particular user at a receiver, cross correlation is performed on the received signal using the unique user code sequence. In CDMA systems, inter-user interference is minimized using one of two possible techniques.

The first technique for minimizing inter-user interference is to modulate the user signals using an orthogonal basis of wideband functions, e.g., Walsh basis. Specifically, at a given instant in time, each user selects (according to its unique code) a different basis function from the orthogonal basis, ensuring zero cross correlation between the different users. The, basis function used by each user may be changed on a symbol by symbol basis, while still ensuring that different users use different functions. The orthogonal basis itself may be changed on a symbol by symbol basis. The result is that each user occupies the entire channel bandwidth, while user cross correlation is kept to zero. The disadvantage of this approach is that in order to build a wideband (and frequency overlapping) orthogonal basis, the user data generally needs to be time synchronized since the orthogonal base construction assumes time synchronization.

A second technique for minimizing inter-user interference which does not require that the user data be time synchronized is to modulate each symbol using a pseudo randomly selected wideband waveform, which is selected according to the unique code for each user. The wideband waveform may be generated by multiplying the user data by a pseudo random sequence, referred to as a spreading sequence. This approach minimizes inter-user interference, but does not reduce the interference to zero. However, the lower the signaling rate (baud rate) is versus its bandwidth, the lower the cross correlation will be. Thus, in CDMA the signaling rate of each user is usually much smaller than the channel bandwidth it occupies in order to make the inter-user interference manageable. Typically, a ratio of 1/100 or less is common.

The above two methods for minimizing inter-user interference may be combined, for example, when it is possible to group users, such that time synchronization exists within a group, although time synchronization may not exist across groups.

CDMA transmission is well known to those of skill in the art. A comparison between CDMA and FDMA/TDMA may be found in Proakis, "Digital Communications", Chapter 15, which is incorporated herein by reference. Also, an example of the combination of the above two approaches for minimizing inter-user interference (i.e., combining a Walsh basis within a group and a spreading sequence across groups) may be found in TIA/EIA/IS-95 "Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System", which is incorporated herein by reference.

The multitone transmission schemes described above, DMT, VCMT and CDMA, may be conceptually viewed as a two-dimensional matrix, with time as the horizontal axis and frequency as the vertical axis. In the presence of ingress (narrowband interference), in the case of CDMA, all codes are corrupted by the ingress, while in VCMT, a single row (or tone) is corrupted, and in DMT, the ingress affects primarily a single row (or tone) with a much lesser effect on adjacent rows. In the presence of impulse (burst interference), the effect on CDMA and DMT is the corruption of a single symbol, while the effect on VCMT is the corruption of primarily a single symbol.

To overcome these problems, data communications systems often rely on error detection and error correction schemes, to detect the occurrence of a data error and to correct a data error, respectively. One simple form of error detection is the use of a parity bit associated with each block of data to indicate whether the particular block contains an odd or even number of 1 bits. However, this is a very simple scheme which has numerous disadvantages. It is a simple type of error detection scheme which is capable of accurately detecting up to one bit error per data block. Moreover, the use of a parity bit cannot detect the occurrence of two bit errors in a data block, since this is not even detected as a parity violation. Additionally, the use of a parity bit only detects errors; it cannot correct errors. Any time that an error is detected, the receiving location typically requests retransmission of the particular data block from the transmitting location.

One type of error correction scheme commonly used in data communications systems is the use of redundant data transmissions and a voting circuit at the receiving location. In such a system, the data being transmitted is repeated a number of times, such as five. At the receiving location, all five data blocks are received and processed by a voting circuit which compares the five received versions of each data bit and determines the bit to be a 1 or 0 based on the voting consensus. Although such a system is capable of detecting and correcting data errors, it does so at a great cost in terms of the effective data throughput or transmission rate. This is due to the fact that each data block must be repeated a number of times.

The above-mentioned correction/detection schemes are examples of binary block codes. Specifically, an (n,k,d) binary block code is a set of 2^k binary codewords of block length n and minimum distance d (i.e., coding distance). The transmitted data is partitioned into binary blocks of length k, then each block is mapped into a binary codeword of length n, which is then modulated and transmitted through the channel, or sub-channels in the case of multiple sub-channels, such as in DMT or VCMT. This block code is capable of correcting up to $t=(d-1)/2$ errors within each codeword.

As mentioned above, there are cases where channel errors occur in non-frequent bursts, the length of which exceeds the error correction capability of the code. These cases are handled by interleaving the data stream before it is modulated and transmitted through the channel. Functionally, an interleaver is a memory device which is used to rearrange and separate the codewords or frames which are to be transmitted. Although certain aspects of the present invention are described by way of reference to interleavers, such as block interleavers, it should be understood that any type of interleaving, such as for example, convolutional interleaving, may be used. The terms codeword and frame are used interchangeably herein where a frame includes only one codeword. Instead of transmitting a succession of complete codewords, the interleaver allows the transmission of a portion (such as a byte) of a first codeword, followed by a portion of a second codeword, and so on. Henceforth, these portions will be referred to as either symbols or codeword symbols. In this way, if an error burst occurs during transmission, the error burst will not be localized to one particular frame. Rather, the errors will be spread across several codewords. If the errors were completely within one codeword, they may exceed the number of errors which the system can inherently correct for by the use of a block code. By spreading the data errors across several blocks, the number of errors within each block may be reduced to the point where the system is capable of correcting the data errors.

In a simple interleaver, data is written into the memory in columns and then read out in rows for subsequent transmission. At the receiver end, the received data is written into a de-interleaver in rows and then read out in columns. The interleaver rearranges the data within the codewords, and the de-interleaver essentially performs the reverse process to

reconstruct the codewords for subsequent use. In this type of interleaver, all the data write operations are carried out as a group, and then the data read operations are carried out as a group. This type of interleaving, referred to as block interleaving, introduces latency of one block at the transmitter and one block at the receiver, due to the fact that a complete block has to be written before it can be read.

SUMMARY OF THE INVENTION

The present invention is for an encoding/framing scheme for multitone modulation over impulsive channels. The encoding/framing scheme allows efficient operation in multipoint to point channels which are affected by ingress (narrowband noise) and impulsive (burst) interference. The coding is achieved using a concatenated approach, with the inner code being Trellis Coded Modulation (TCM), using, for example, convolutional coding, and the outer code being a Reed Solomon (RS) code. Two dimensional interleaving is performed, with one dimension being time, and the other dimension being frequency (tones or sub-channels). In contrast to conventional coding schemes, the TCM coding provided by the present invention is quite effective in dealing with impulse noise effects. The present invention is also for a two level interleaving approach, in which different interleaving is performed on different levels. According to one embodiment of the present invention, the user data is RS encoded, and a portion of the RS encoded data is interleaved and filled along columns for transmission using a multitone transmission system. The remaining portion of the RS encoded user data is then TCM encoded, interleaved and effectively filled along rows for subsequent transmission. In another embodiment according to the present invention, a portion of the user data is RS encoded, interleaved and filled along columns for transmission, while the remaining portion of the user data is instead TCM encoded, interleaved and effectively filled along rows for subsequent transmission. The actual filling of the TCM encoded data may be performed along columns; however, the interleaving essentially introduces a reversal between columns and rows, such that the effective filling of data is along rows. In addition to the reversal of columns and rows, the interleaving also introduces time separation of symbols, which is a function of the interleaver depth.

The advantage of this approach is that the RS code symbols are filled in columns, while the TCM codewords are filled in rows. The first effect is that the number of RS bytes that are impacted by an impulse is reduced. Otherwise, an impulse could affect a larger number of RS bytes if they were filled in rows. Although the impacted RS bytes might be more severely impacted, due to the nature of the RS coding, it does not matter whether the RS byte is corrupted by one bit or by many bits. Thus, the advantage of the present invention is reducing the total number of RS bytes which contain any corrupted bits. The second effect is that the TCM codewords are filled in along rows, which in the case of an impulse, reduces the number of bits corrupted in each corrupted codeword. Again, because of the nature of the TCM coding, it is preferable to reduce the maximum number of corrupted bits likely to be experienced, in order to reduce the coding redundancy required of all codewords.

The present invention is also for a diagonalization scheme which provides immunity against impulse noise, while at the same time allowing for a simple method of utilizing tones of different loading. According to the diagonalization principle, data packets are spread over time in a diagonal fashion, such that an impulse noise affects more than one user's packets, with the effect on each being reduced. In this way, a code having lower redundancy can be used since the amount of corruption expected in one user's data packet will be reduced.

The present invention will become more apparent from the following Brief Description of the Drawings and Description of Preferred Embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a multitone modulation data transmission system;

FIG. **2** is an illustration of multitone data transmission as a function of time;

FIG. **3A** is an illustration of multitone data transmission as a function of time, with rows and columns interchanged, for the case of uniform tone loading;

FIG. **3B** is an illustration of multitone data transmission as a function of time, with rows and columns interchanged, for the case of nonuniform tone loading;

FIG. **4** is an illustration of diagonalization in accordance with the present invention for multitone data transmission as a function of time;

FIG. **5** is a block diagram of the framing approach of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** shows a block diagram of a multitone modulation system. Such a system may be used in a multipoint to point channel, in which the communication channel is shared between users (stations), using, for example, Time Division Multiple Access (TDMA). A TDMA system allocates discrete amounts of the frequency bandwidth to each user, allowing many simultaneous conversations or connections. In a TDMA system, each user is assigned a specific timeslot for transmission of the data packets associated with that user. The "packet" is the user transmission unit of data. Referring now to FIG. **1**, a data packet **12** is processed by a framing block **14** which performs the coding and interleaving functions used to improve immunity against interference. The packets processed by the framing block **14** are passed to the multitone modulation block **16** which performs the multitone modulation, as described in detail below, and generates a baseband multitone signal. The baseband multitone signal is then passed to frequency upconversion block **18** which converts the baseband signal to its assigned frequency band.

The present invention concatenates TCM inner coding and RS outer coding. Specifically, in the TCM coding, signal space is partitioned into cosets encoded by a rate ½ convolutional encoder. TCM coding is very efficient in white noise channels. As a result, it efficiently utilizes the spreading effect of impulse energy between tones, assuming proper interleaving. Although the input noise may not be pure white noise, but may in fact be colored, the adaptive, per-tone bit loading effectively provides white noise conditions for the coset encoding.

The RS outer coding provides additional protection against noise. It is mostly effective against strong impulses which have penetrated to the TCM parallel transitions layer. Due to the high performance of the TCM coding and the long symbols used in VCMT, it is possible to use RS coding with lower redundancy.

In accordance with the two dimensional interleaving according to the present invention, coded data is time interleaved and assigned to tones in a way which evenly divides the effect of ingress and impulse noise over multiple

codewords and among multiple users. First, inter-user interleaving is performed using a diagonal structure to assign tones among different users. The diagonalization scheme complements the inherent multitone immunity to impulse noise. As a result, impulse energy is divided between tones, and tones are assigned to different users. Intra-user interleaving is used to interleave codewords within a packet in a way which divides the interference effect between codewords, while keeping the RS symbols aligned (columnwise) with the impulse interference. This alignment approach makes use of the RS code's efficient burst handling capabilities.

FIG. **2** illustrates a multitone modulation scheme utilizing TDMA. A number of tones T are positioned at different frequency bands along the vertical frequency axis. Data packets are transmitted in a time-wise fashion along the horizontal time frequency axis. In the specific example shown in FIG. **2**, User **1** is allocated two timeslots, while User **2** is allocated five timeslots following the transmission of User **1**. The presence of impulse noise will act to corrupt a column of data. Because impulse noise has the potential to corrupt a very high percentage of data for a particular user, the data for all users must be encoded using a high degree of redundancy in the event that it is corrupted. This approach is extremely inefficient in that user data for all users must be encoded to have a very high degree of compensation when only a small number of users are likely to have their data corrupted.

One approach to reducing the effect of impulse noise is shown in FIG. **3**A, in which the columns and rows are essentially switched. Reducing the effect of impulse noise will result in a reduction in the amount of encoding or compensation that is required to effectively deal with expected noise events. As shown in FIG. **3**A, each timeslot along the horizontal time axis is split among users. The tones T in FIG. **3**A are assumed to all have the same bit loading. The specific example shown in FIG. **3**A illustrates two "timeslots" for two users, User **1** and User **2**. As a result, the effect of any impulse noise will be split among different users, and will not be concentrated on the data of a single user. Essentially, the corrupted data is distributed more evenly among users, thus reducing the maximum percentage of corrupted data which is likely to be experienced. As a result, the required coding redundancy or compensation necessary to deal with expected errors may be reduced. This is in contrast to the approach illustrated in FIG. **2**, in which case the impulse noise may be completely targeted on the data of a single user, resulting in a large number of errors, thus requiring a high degree of redundancy or compensation in the coding of all user data.

Although the approach of FIG. **3**A may increase noise immunity, it still has its disadvantages. Specifically, the switching of columns and rows is only practical for multitone transmission systems in which the individual tones all have the same loading. In the simplistic example of FIG. **2**, User **1** is transmitting an amount of data corresponding to seven sub-channels for two time intervals. Similarly, User **2** is transmitting an amount of data corresponding to the same seven sub-channels, but for five time intervals. When the rows and columns are reversed, as in FIG. **3**A, the amount of data for User **1** now corresponds to the first two sub-channels, but for a longer period of time. Similarly, the amount of data for User **2** corresponds to the next five sub-channels, for the same period of time. This limitation, i.e., uniform loading, is required so that the system can be easily and practically implemented with uniform sized rectangles, so that in this example, the data transmitted by seven sub-channels for two time periods, would be the same amount of data as that transmitted by two sub-channels for seven time periods. Of course, the system may be implemented with nonuniform tone loading; however, the system must then have to contend with irregularly shaped rectangles.

The application of the principles of FIG. **3**A (i.e., switching of columns and rows) in the case of nonuniform bit loading is illustrated in FIG. **3**B. For this illustration of nonuniform bit loading, it is assumed that tones **11** and **13** have bit loading of 2, while tones **15**, **17**, **19**, **21** and **23** have bit loading of 1. Thus, in the original case of FIG. **2**, User **1** data will correspond to tones **11** and **13** (two bits each) for two time periods, or eight bits, plus tones **15**, **17**, **19**, **21** and **23** (one bit each) for two time periods, or 10 bits, for a total of 18 bits. Similarly, the data for User **2** will correspond to tones **11** and **13** (two bits each) for five time periods, or 20 bits, plus tones **15**, **17**, **19**, **21** and **23** (one bit each) for five time periods, or 25 bits, for a total of 45 bits. Thus, if the rows and columns are reversed, as shown in FIG. **3**B, User **1** is now assigned tones **11** and **13** (two bit loading for each), which require five time periods to transmit the 18 bits for User **1**. Similarly, User **2** is assigned tones **15**, **17**, **19**, **21** and **23** (one bit loading for each), which require nine time periods to transmit the 45 bits for User **2**. As a result, the system must contend with irregular shaped rectangles, as shown in FIG. **3**B.

The present invention solves the above problem by utilizing the diagonalization principle illustrated in FIG. **4**. As shown in FIG. **4**, a frequency (sub-channel) versus time mapping is used to transmit the data packets for the different users. The specific mapping shown in FIG. **4** is a linear frequency versus time mapping having a slope of 1, i.e., the tone index is incremented by one for each successive symbol time period. Other slopes may be used in accordance with the principles of the present invention. In the illustrated example, the data packet for User **1** consists of two diagonals **22**, **24**, while the data packet for User **2** consists of five diagonals, **26**, **28**, **30**, **32** and **34**. Because the data for the different users is spread out in time, the effect of impulse noise is also similarly spread out. For example, the impact of impulse noise **36** will be spread out over both User **1** and User **2**. The advantage of this approach is that the amount of corrupted data that any one user is expected to experience is decreased. As a result, the level of redundancy or compensation required in the coding for such data is also reduced, thereby reducing the inefficiency and overhead associated with proper data transmission. More importantly, the present invention provides added immunity against impulse noise, while at the same time allowing for the simple and easy use of differently loaded sub-channels. As shown in FIG. **4**, the same tones are used for the users as in the approach of FIG. **2**, just that the output of the tones is spread out over time.

A block diagram of the framing scheme according to the present invention is shown in FIG. **5**. As shown in FIG. **5**, the input data, for example, in the form of data packets, is input to an RS coder **52**. The RS coder **52** may, for example, utilize a polynomial over GF(256) (Galois Field) as defined in the DOCSIS/MCNS standard, i.e., $x^8+X^4+X^3+x^2+1$. The codeword size for the RS coder **52** may be programmable, as is T, the number of corrected errors, with T being in the range of 1 to 10. Alternatively, there may be no FEC coding at all.

The DOCSIS standard is the Data Over Cable Service Interface Specification, Radiofrequency Interface Specification, SP-RFI-102-971008 and SP-RFI-I04-980724, published by Cable Television Laboratories, Inc., 400 Cen-

tennial Drive, Louisville, Colo. Reference is also made to the present inventor's Variable Constellation Multitone Modulation (VCMT) Proposal for High Capacity Upstream Physical Layer, Project IEEE 802.14a HI_PHY Study Group, Document #IEEE 802.14a/98-013, available from the IEEE (Piscataway, New Jersey), the contents of which are hereby incorporated by reference.

The data output by the RS coder **52** is then input to an interleaver **54**. The interleaver stage **54** may be optional, dependent on a number of factors, including packet size. Generally, it is advantageous to perform packet interleaving only if the data packet includes more than one RS codeword. The interleaver **54** may be a packet interleaver, such as a byte-wise block interleaver which functions to interleave RS symbols between codewords. The interleaver **54** is generally used when the packets contain multiple RS codewords, i.e., sufficiently large packets, such as 1 kbit or more. The interleaver input is X(n), for n=0, , , (N-i), where N is the block size in bytes. The interleaver output Y(n) is as follows (from left to right), with "J" being a programmable parameter:

X(0)	X(J)	X(2*J)	. . .	X(floor(N/J)*J)
X(1)	X(1 + J)	X(1 + 2*J)	. . .	X(1 + floor((N − 1)/J*J)
. . .				
X(J − 1)	X(2*J − 1)	. . .		X(J − 1 + floor((N − (J − 1))/J)*J)

The output bytes, Y(n), are serialized msb first. If the interleaver is polled after its input has been exhausted, it then outputs zeros.

The data output by the interleaver **54** is rearranged into a serial bit stream (MSB first) and then scrambled in scrambler **56**, which is used to randomize the coded and interleaved data. Scrambler **56** may, for example, be implemented in accordance with the scrambler defined in the ADSL (Asymmetric Digital Subscriber Line) specification, TIEI.4/98-007R1, promulgated by the American National Standards Institute (ANSI) (1998). The scrambler may be defined by a 15-bit polynomial, such as $x^{15}+x^{14}+1$, with a programmable seed. The scrambler **56** may be effectively bypassed by using a seed of zero. The scrambler **56** generates a randomizing sequence according to the rule: DS(n)=DS(n-14)⊕DS(n-15). The serialized bit stream from the interleaver **54** is XORed with DS(n). Specifically, data bit "n" is XOR'd with DS(n).

The data output by the scrambler **56** is then divided by level splitter **58** into the two levels of the TCM encoder. If the system utilizes only RS coding, all the data bits are assigned to the upper level **60**, and the lower level **70** is disabled. Splitter **58** essentially divides the serial bit stream into a group of data bits to be processed by the lower level **70**, and the remaining data bits to be processed by the upper level **60**. The number of bits assigned to the lower level **70** corresponds to one bit for each of the symbols in the packet for the particular user. Thus, in the case of the example illustrated in FIG. **4**, 14 bits would be assigned to the lower level **70** for the packet of User **1**, while 35 bits would be assigned to the lower level **70** for the packet of User **2**. The actual number of assigned, usable bits may be reduced due to overhead signals, such as pilot tones. To simplify the implementation of the system, the lower level bits may be selected as the first bits in the serial bit stream. Alternatively, any selection scheme may be used; however, this would increase system complexity in terms of keeping track of the particular bits in the serial data stream.

In the upper level **60** of the TCM encoder, data bits are assigned to parallel transitions in a column-wise fashion by column filler **62**. Essentially, a two dimensional matrix is filled, with the row index being tone frequency (vertical axis, FIG. **4**) and the column index being symbol time (horizontal axis, FIG. **4**). The mapping is performed column by column, proceeding from top to bottom (decreasing tone frequency). The leftmost column is filled first, and the rightmost column is filled last (increasing time). At each location, an m-tuple is placed according to the corresponding constellation rule (or bit loading) for the particular tone. Because only parallel transitions are mapped, m=(tone bit loading−2). The "−2" term takes account of the fact that the group filler, discussed below, inserts two bits into each location. Certain matrix elements are used to transmit overhead bits, instead of user payload data. The column filler **62** operates to fill in the symbols in absolute vertical columns, regardless of whether diagonalization is being used. The column filler **62** fills in columns, stopping only at packet boundaries between users, i.e., at the end of a time slot for a particular user.

Referring to the specific example of FIG. **4**, let the rows be labeled A through H, with A being the top row, and H being the bottom row. Similarly, let the diagonals be labeled **1** through **7**, with **1** being the left most diagonal, and **7** being the rightmost diagonal. For User **1**, the column filler **62** operates to fill the symbols in the order: A**1**, A**2**, B**1**, B**2**, C**1**, . . . F**2**, G**1**, G**2**. For User **2**, the column filler **62** operates to fill the symbols in the order: A**3**, A**4**, B**3**, A**5**, B**4**, C**3**, . . . F**7**, G**6**, G**7**. For each of the symbols filled in by the column filler **62**, the two LSBs are left empty, since these will be filled in by the group filler, explained in detail below.

In the lower level **70** of the TCM encoder, data is first collected into groups by group collector **72**. Groups are consecutive diagonals that are combined. Groups are typically used to create larger TCM words, such that the complexity of the TCM decoding is reduced. In this manner, a packet can be represented as one or more groups, with each group corresponding to one or more consecutive diagonals. The group size is programmable. The group collector **72** collects successive data bits from the level splitter **58**, up to the size of the group, and also outputs the number of bits in the group, i.e., Group_Size. For example, in the case of the example illustrated in FIG. **4**, if for User **2**, diagonals **3**, **4** and **5** were considered one group, while diagonals **6** and **7** were considered a second group, group collector would divide the incoming bit stream into a first group of 21 bits and a second group of 14 bits, corresponding to the first and second groups of diagonals.

After grouping, the data is rate 1/2 convolutionally encoded (constraint length **6**) by coder **74**, which block encodes $Group_{13}$ Size bits. Consecutive groups are individually encoded using a tail biting method. In this way, the single LSB for each of the symbols is encoded into a bit pair, which will be inserted into the corresponding symbol in the place left open for the two LSBs by the column filler **62** discussed above. This bit pair is used to select the particular coset within a constellation and the higher order bits (upper level) are used to select the parallel transition.

Next, the group of bit pair LSB bits for an entire group is interleaved by interleaver **76** which performs block inter-

leaving. The interleaver **76** operates on encoded bit pairs (cosets). The input to the interleaver **76** is X(n), for n=0. . . (N–i), where N is Group_Size. The interleaver output Y(n), with J being a programmable parameter, is similar to the output of interleaver **54**, i.e.,

X(0)	X(J)	X(2*J)	. . .	X(floor(N/J)*J)
X(1)	X(1 + J)	X(1 + 2*J)	. . .	X(1 + floor((N − 1)/J*J)
. . .				
X(J − 1)	X(2*J − 1)	. . .		X(J − 1 + floor((N − (J − 1))/J)*J)

The data output by the interleaver **76** is assigned to a particular symbol by group filler **78**. Group filling is performed in a column-wise fashion within a group. The group filler **78** assembles the encoded and interleaved cosets and assigns them to the appropriate tones. The mapping is performed in an absolute, vertical column by column approach (even if the data symbols are diagonalized according to one aspect of the present invention), proceeding from top to bottom (decreasing tone frequency). The group filling is performed along vertical columns, stopping at group boundaries. The leftmost column is filled first, and the rightmost column is filled last (increasing time). Thus, in the case of the example illustrated in FIG. **4**, if the data packet for User **2** is partitioned into a first group (diagonals **3**, **4** and **5**) and a second group (diagonals **6** and **7**), the group filler would operate to fill in the two LSBs for the symbols in the following order: A**3**, A**4**, B**3**, A**5**, B**4**, C**3**, B**5**, C**4**, D**3**, . . . F**7**, G**6**, G**7**.

The actual filling of the TCM encoded data is performed along columns; however, the interleaving essentially introduces a reversal between columns and rows, such that the effective filling of data is along rows. In addition to the reversal of columns and rows, the interleaving also introduces time separation of symbols, which is a function of the interleaver depth. The time separation of the symbols is advantageous in that it is easier for the TCM coding to deal with corrupted symbols that are not adjacent in time. As indicated above, the time separation of symbols provided by the interleaver is a function of the interleaver depth. Thus, the depth of the interleaver should be set to be at least equal to the number of rows in a group, multiplied by the expected impulse length (in symbol time periods).

As with the filling of the upper level, the overhead symbols are accounted for in the filling process. The column filler **62** operates on the MSBs of the data word, while the group filler **78** operates on the LSB's of the data word.

The outputs of the upper stream **60** and the lower stream **70** are combined into m-tuples (QAM symbols), and temporarily stored in a FIFO buffer **80**. The data is then delivered from the FIFO buffer **80** to a QAM mapper **82**. The FIFO buffer **80** introduces the appropriate delay required to output the m-tuples according the diagonalization principle of the present invention.

The specific example illustrated in FIG. **5** performs RS coding on the entire user data stream and then performs TCM encoding on a portion of the user data stream. Alternatively, the two level encoding approach of the present invention may be carried out such that RS encoding only is performed on a portion of the data stream and TCM encoding only is performed on the remainder of the data stream. In such an implementation, RS coder 52 and packet interleaver **54** would instead be placed in the upper level **60**, between level splitter **58** and column filler **62**. Scrambler **56** may be implemented prior to the level splitter, as in FIG. **5**, or alternatively, it may be implemented following the packet interleaver **54** and before the column filler **62**.

The two level encoding approach of the present invention, as well as the diagonalization of the present invention, may be performed separately, or they may be performed together. The diagonalization may be implemented by either the column filler **62** and group filler **78** together, or alternatively by the FIFO **80**. These blocks are programmed to map the data to the appropriate symbols, to implement (or not implement) the diagonalization.

The input to the QAM mapper **82** is data in the form of m-tuples which are to be mapped into QAM symbols, for example, ranging from QPSK to 256-QAM, tone by tone. The constellation mapping may be the same as that used in ADSL. In order to randomize the overhead channel symbols, a phase scrambling sequence is applied to the output symbols. However, to simplify implementation, the phase scrambler is applied to all symbols, not just the overhead symbols. For example, the phase scrambling sequence may be generated by a pseudo-random generator composed of a linear feedback shift register of length **21**, and initialized by a user programmable seed. Consecutive output pairs from the pseudo-random generator, e.g., (n, n+1), (n+2, n+3), . . . denoted (a, b) are converted into numbers 2a+b (the sum is "2a+b" because the "a" bit is the MSB, i.e., 2^1) and the sum (2a+b) is used to select the amount of rotation to be applied to the symbol, according to the following table:

2a + b		Phase Rotation
0	→	0
1	→	+π/2
2	→	π
3	→	−π/2

The diagonalization principle of the present invention utilizes the same diagonal slope for all users, taking into account trade-offs between latency and noise immunity. The minimum transmission element is a full diagonal, and appropriate data padding is utilized to result in a whole number of diagonals. Each packet may contain overhead bits (e.g., pilot tones) in addition to payload data. Although the overhead bits are not coded, they are still counted when computing the packet size and mapping the data into tones.

The output from the QAM mapper **82** is provided to a modulator (not shown) which implements the particular signal modulation desired, e.g., VCMT, CDMA, etc.

The framing scheme according to the present invention may also be performed in a CDMA system, in which case the modulator (not shown) may, for example, be a CDMA-type modulator in accordance with the TIA/EIA/IS-95 "Mobile Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System". In the case of a CDMA implementation of the framing scheme according to the present invention, the TCM encoded data may be filled along rows, while the RS encoded data may be filled along columns.

The framing scheme and diagonalization scheme according to the present invention may be implemented separately or together, depending on the particular application and data transmission system. For example, in the case of a VCMT implementation utilizing both diagonalization and framing according to the present invention, the RS encoded data may be filled along columns, while the TCM encoded data is filled along diagonals.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of arranging and transmitting data in a multitone modulation system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding a first portion of said data according to a first error correcting code to produce first encoded data;

encoding a second portion of said data according to a second error correcting code to produce second encoded data;

arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

arranging said second encoded data according to rows, wherein each row corresponds to one of said plurality of tones

matching said first error correcting code, said second error correcting code, and said arranging steps to a type of noise the modulation is sensitive to; and

utilizing said plurality of tones to transmit said first encoded data and said second encoded data.

2. The method of claim **1**, wherein said first error correcting code is a Reed-Solomon code.

3. The method of claim **1**, wherein said second error correcting code is a TCM code.

4. The method of claim **1**, further comprising the following step after the first encoding step:

interleaving said first encoded data, and wherein said arranging step arranges the interleaved first encoded data.

5. A method of arranging and transmitting data in a multitone modulation system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding a first portion of said data according to a first error correcting code to produce first encoded data;

encoding a second portion of said data according to a second error correcting code to produce second encoded data;

arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

interleaving and arranging said second encoded data such that it is spread over time;

matching said first error correcting code, said second error correcting code, and said arranging steps to a type of noise the modulation is sensitive to; and

utilizing said plurality of tones to transmit said first encoded data and said second encoded data.

6. The method of claim **5**, wherein said first error correcting code is a Reed-Solomon code.

7. The method of claim **5**, wherein said second error correcting code is a TCM code.

8. The method of claim **5**, further comprising the following step after the first encoding step:

interleaving said first encoded data, and wherein said arranging step arranges the interleaved first encoded data.

9. A method of arranging and transmitting data in a multitone system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, said tones corresponding to rows and said symbol periods corresponding to columns, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding said data according to a first error correcting code to produce first encoded data;

interleaving said first encoded data to produce an interleaved data stream;

splitting said interleaved data stream into upper level data and lower level data;

arranging said upper level data along columns;

encoding said lower level data according to a second error correcting code to produce second encoded data;

arranging said second encoded data according to rows; and

utilizing said plurality of tones to transmit said upper level data and said second encoded data.

10. The method of claim **9**, further comprising the step of scrambling said interleaved data prior to said splitting step.

11. The method of claim **9**, wherein said splitting step operates to assign one bit of said interleaved data stream to said lower level, for each symbol of said data.

12. The method of claim **11**, wherein said splitting step operates to assign the first N bits of said interleaved data stream to said lower level, in the case where said data comprises N symbols.

13. The method of claim **9**, wherein after said splitting step and prior to said second encoding step, said method includes the step of arranging said lower level data into one or more groups.

14. The method of claim **9**, wherein said step of arranging upper level data operates to arrange a predetermined number of bits less than a full amount of data bits in each symbol, and said step of arranging said second encoded data operates to arrange said predetermined number of bits in each symbol.

15. The method of claim **9**, wherein prior to said utilizing step, said method includes the step of phase scrambling said upper level data and said second encoded data in accordance with said second encoded data.

16. A method of arranging and transmitting data in a multitone system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, said tones corresponding to rows and said symbol periods corresponding to columns, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding said data according to a first error correcting code to produce first error correcting encoded data;

interleaving said first encoded data to produce an interleaved data stream;

splitting said interleaved data stream into upper level data and lower level data;

arranging said upper level data along columns;

encoding said lower level data according to a second error correcting code to produce second encoded data;

interleaving and arranging said second encoded data such that it is spread over time; and

utilizing said plurality of tones to transmit said upper level data and said second encoded data.

17. A method of arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding a first portion of said data according to a first error correcting code to produce first encoded data;

encoding a second portion of said data according to a second error correcting code to produce second encoded data;

arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

arranging said second encoded data according to rows, wherein each row corresponds to one of said plurality of codes;

matching said first error correcting code, said second error correcting code, and said arranging steps to a type of noise the modulation is sensitive to; and

utilizing said plurality of modulation codes to transmit said first encoded data and said second encoded data.

18. The method of claim **17**, wherein said first error correcting code is a Reed-Solomon code.

19. The method of claim **17**, wherein said second error correcting code is a TCM code.

20. The method of claim **17**, further comprising the following step after the first encoding step:

interleaving said first encoded data, and wherein said arranging step arranges the interleaved first encoded data.

21. A method of arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding a first portion of said data according to a first error correcting code to produce first encoded data;

encoding a second portion of said data according to a second error correcting code to produce second encoded data;

arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

interleaving and arranging said second encoded data such that it is spread over time;

matching said first error correcting code, said second error correcting code, and said arranging steps to a type of noise the modulation is sensitive to; and

utilizing said plurality of modulation codes to transmit said first encoded data and said second encoded data.

22. The method of claim **21**, wherein said first error correcting code is a Reed-Solomon code.

23. The method of claim **21**, wherein said second error correcting code is a TCM code.

24. The method of claim **21**, further comprising the following step after the first encoding step:

interleaving said first encoded data, and wherein said arranging step arranges the interleaved first encoded data.

25. A method of arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, said modulation codes corresponding to rows and said symbol periods corresponding to columns, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding said data according to a first error correcting code to produce first encoded data;

interleaving said first encoded data to produce an interleaved data stream;

splitting said interleaved data stream into upper level data and lower level data;

arranging said upper level data along columns; encoding said lower level data according to a second error correcting code to produce second encoded data;

arranging said second encoded data according to rows; and

utilizing said plurality of modulation codes to transmit said upper level data and said second encoded data.

26. The method of claim **25**, further comprising the step of scrambling said interleaved data prior to said splitting step.

27. The method of claim **25**, wherein said splitting step operates to assign one bit of said interleaved data stream to said lower level, for each symbol of said data.

28. The method of claim **27**, wherein said splitting step operates to assign the first N bits of said interleaved data stream to said lower level, in the case where said data comprises N symbols.

29. The method of claim **25**, wherein after said splitting step and prior to said second encoding step, said method includes the step of arranging said lower level data into one or more groups.

30. The method of claim **25**, wherein said step of arranging upper level data operates to arrange a predetermined number of bits less than a full amount of data bits in each symbol, and said step of arranging said second encoded data operates to arrange said predetermined number of bits in each symbol.

31. The method of claim **25**, wherein prior to said utilizing step, said method includes the step of phase scrambling said upper level data and said second encoded data in accordance with said second encoded data.

32. A method of arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, said modulation codes corresponding to rows and said symbol periods corresponding to columns, comprising the following steps:

inputting data comprising a plurality of data symbols;

encoding said data according to a first error correcting code to produce first encoded data;

interleaving said first encoded data to produce an interleaved data stream;

splitting said interleaved data stream into upper level data and lower level data;

arranging said upper level data along columns;

encoding said lower level data according to a second error correcting code to produce second encoded data;

interleaving and arranging said second encoded data such that it is spread over time; and

utilizing said plurality of modulation codes to transmit said upper level data and said second encoded data.

33. The method of claim **7** wherein the step of interleaving and arranging arranges the second encoded data according to one of rows and columns.

34. An apparatus for arranging and transmitting data in a multitone modulation system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding a first portion of said data according to a first error correcting code to produce first encoded data;

means for encoding a second portion of said data according to a second error correcting code to produce second encoded data;

means for arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

means for arranging said second encoded data according to rows, wherein each row corresponds to one of said plurality of tones;

means for matching said first error correcting code, said second error correcting code, and said means for arranging to a type of noise the modulation is sensitive to; and

means for utilizing said plurality of tones to transmit said first encoded data and said second encoded data.

35. An apparatus for arranging and transmitting data in a multitone modulation system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding a first portion of said data according to a first error correcting code to produce first encoded data;

means for encoding a second portion of said data according to a second error correcting code to produce second encoded data;

means for arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

means for interleaving and arranging said second encoded data such that it is spread over time;

means for matching said first error correcting code, said second error correcting code, and said means for arranging to a type of noise the modulation is sensitive to; and

means for utilizing said plurality of tones to transmit said first encoded data and said second encoded data.

36. An apparatus for arranging and transmitting data in a multitone system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, said tones corresponding to rows and said symbol periods corresponding to columns, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding said data according to a first error correcting code to produce first encoded data;

means for interleaving said first encoded data to produce an interleaved data stream;

means for splitting said interleaved data stream into upper level data and lower level data;

means for arranging said upper level data along columns;

means for encoding said lower level data according to a second error correcting code to produce second encoded data;

means for arranging said second encoded data according to rows; and

means for utilizing said plurality of tones to transmit said upper level data and said second encoded data.

37. An apparatus for arranging and transmitting data in a multitone system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, said tones corresponding to rows and said symbol periods corresponding to columns, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding said data according to a first code to produce first error correcting encoded data;

means for interleaving said first encoded data to produce an interleaved data stream;

means for splitting said interleaved data stream into upper level data and lower level data;

means for arranging said upper level data along columns;

means for encoding said lower level data according to a second error correcting code to produce second encoded data;

means for interleaving and arranging said second encoded data such that it is spread over time; and

means for utilizing said plurality of tones to transmit said upper level data and said second encoded data.

38. An apparatus for arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding a first portion of said data according to a first error correcting code to produce first encoded data;

means for encoding a second portion of said data according to a second error correcting code to produce second encoded data;

means for arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

means for arranging said second encoded data according to rows, wherein each row corresponds to one of said plurality of codes;

means for matching said first error correcting code, said second error correcting code, and said means for arranging to a type of noise the modulation is sensitive to; and

means for utilizing said plurality of modulation codes to transmit said first encoded data and said second encoded data.

39. An apparatus for arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding a first portion of said data according to a first error correcting code to produce first encoded data;

means for encoding a second portion of said data according to a second error correcting code to produce second encoded data;

means for arranging said first encoded data according to time-wise columns, each of said time-wise columns corresponding substantially to a symbol period;

means for interleaving and arranging said second encoded data such that it is spread over time;

means for matching said first error correcting code, said second error correcting code, and said means for arranging to a type of noise the modulation is sensitive to; and

means for utilizing said plurality of modulation codes to transmit said first encoded data and said second encoded data.

40. An apparatus for arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, said modulation codes corresponding to rows and said symbol periods corresponding to columns, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding said data according to a first error correcting code to produce first encoded data;

means for interleaving said first encoded data to produce an interleaved data stream;

means for splitting said interleaved data stream into upper level data and lower level data;

means for arranging said upper level data along columns;

means for encoding said lower level data according to a second error correcting code to produce second encoded data;

means for arranging said second encoded data according to rows; and

means for utilizing said plurality of modulation codes to transmit said upper level data and said second encoded data.

41. An apparatus for arranging and transmitting data in a CDMA system having a plurality of modulation codes, each modulation code adapted to transmit a data symbol during a symbol period, said modulation codes corresponding to rows and said symbol periods corresponding to columns, comprising:

means for inputting data comprising a plurality of data symbols;

means for encoding said data according to a first error correcting code to produce first encoded data;

means for interleaving said first encoded data to produce an interleaved data stream;

means for splitting said interleaved data stream into upper level data and lower level data;

means for arranging said upper level data along columns;

means for encoding said lower level data according to a second error correcting code to produce second encoded data;

means for interleaving and arranging said second encoded data such that it is spread over time; and

means for utilizing said plurality of modulation codes to transmit said upper level data and said second encoded data.

42. A method of transmitting data of at least two users to provide inter-user interleaving in a multitone modulation system having a plurality of tones, each tone at a different frequency and adapted to transmit a data symbol during a symbol period, the method comprising the following steps:

inputting user data comprising a plurality of data symbols;

encoding a first portion of said user data according to a first code to produce first encoded data;

encoding a second portion of said user data according to a second code to produce second encoded data, said first and second codes being different;

arranging said first encoded data according to time-wise columns of symbols to be transmitted, each of said time-wise columns corresponding substantially to a symbol period;

arranging said second encoded data according to rows of symbols to be transmitted, wherein each row corresponds to one of said plurality of tones;

matching said first error correcting code, said second error correcting code, and said arranging steps to a type of noise the modulation is sensitive to;

delaying the transmission of successive ones of said symbols to be transmitted; and

utilizing said plurality of tones to transmit the symbols to be transmitted.

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ANSI T1.413-1995

American National Standard

for Telecommunications –

Network and Customer Installation Interfaces – Asymmetric Digital Subscriber Line (ADSL) Metallic Interface

ANSI T1.413-1995

ANSI American National Standards Institute
11 West 42nd Street
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American National Standard
for Telecommunications –

Network and Customer Installation Interfaces – Asymmetric Digital Subscriber Line (ADSL) Metallic Interface

Secretariat

Alliance for Telecommunications Industry Solutions

Approved August 18, 1995

American National Standards Institute, Inc.

Abstract

This standard presents the electrical characteristics of the Asymmetric Digital Subscriber Line (ADSL) signals appearing at the network interface. The physical interface between the network and the customer installation is also described. The transport medium for the signals is a single twisted-wire pair that supports both Message Telecommunications Service (POTS) and full-duplex (simultaneous two-way) and simplex (from the network to the customer installation) digital services.

This interface standard provides the minimal set of requirements for satisfactory transmission between the network and the customer installation. Equipment may be implemented with additional functions and procedures.

American National Standard

Approval of an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by the standards developer.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

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NOTE – The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights.

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Foreword (This foreword is not part of American National Standard T1.413-1995.)

This specification of the layer 1 characteristics of the Asymmetrical Digital Subscriber Line (ADSL) interface to metallic loops was initiated under the auspices of the Accredited Standards Committee on Telecommunications, T1. The specification should be of interest and benefit to network providers and customers using multimedia services.

A single twisted pair of telephone wires is used to connect two ADSL units: one at the central office end (an ATU-C) and one at the remote end (an ATU-R). This standard has been written to define the transport capability of these units on a wide variety of wire pairs and with typical impairments, and to help ensure proper interfacing and interworking when the two units are manufactured and provided independently.

The ADSL simultaneously conveys all of the following: a downstream simplex bearer, a duplex bearer, a baseband analog duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. Nominal downstream bearer rates from 1.536 to 7 Mbit/s may be programmed. Duplex bearer aggregate rates from 16 to 640 kbit/s may be programmed.

Two categories of performance are specified. Category I performance is required for compliance with this standard; performance enhancement options are not required for category I equipment. Category II is a higher level of performance (i.e., longer lines and greater impairments). Category II characteristics are not required for compliance with this standard. Three optional enhancements – trellis coding, transmit power boost, and echo cancellation – are defined for Category II equipment.

A future issue of this standard may address the items listed in annex J.

There are nine annexes to this standard; four are normative, and are considered part of the standard; five are informative, and are provided for information only.

Suggestions for improvements of this standard are welcome. They should be sent to the Alliance for Telecommunications Industries Solutions, 1200 G Street, NW, Suite 500, Washington, DC 20005.

This standard was processed and approved for submission to ANSI by Accredited Standards Committee on Telecommunications T1. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, committee T1 had the following members:

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American National Standard for Telecommunications – Network and Customer Installation Interfaces – Asymmetric Digital Subscriber Line (ADSL) Metallic Interface

1 Scope and purpose

1.1 Scope

This standard describes the interface between the telecommunications network and the customer installation in terms of their interaction and electrical characteristics. The requirements of this standard apply to a single asymmetric digital subscriber line (ADSL). ADSL allows the provision of Plain Old Telephone Service (POTS) and a variety of digital channels. In the direction from the network to the customer premises the digital channels may consist of full duplex low-speed channels and simplex high-speed channels; in the other direction only low-speed channels are provided.

The transmission system is designed to operate on two-wire twisted metallic cable pairs with mixed gauges. The standard is based on the use of cables without loading coils, but bridged taps are acceptable with the exception of unusual situations.

Functions included in the Service Modules, other than those associated with the ATU-R to Service Module interface, are beyond the scope of this standard.

Specifically, this standard:

- describes the transmission technique used to support the simultaneous transport of POTS and both simplex and full-duplex digital channels on a single twisted-pair;
- defines the combined options and ranges of the digital simplex and full-duplex channels provided;
- defines the line code and the spectral composition of the signals transmitted by both ATU-C and ATU-R;
- specifies the receive signals at both the ATU-C and ATU-R;
- describes the electrical and mechanical specifications of the network interface;
- describes the organization of transmitted and received data into frames;
- defines the functions of the operations channel;
- defines the ATU-R to service module(s) interface functions.

1.2 Purpose

This interface standard defines the minimal set of requirements to provide satisfactory simultaneous transmission between the network and the customer interface of POTS and a variety of high-speed simplex and low-speed full duplex channels. The standard permits network providers an expanded use of existing copper facilities. All Layer 1 aspects required to ensure compatibility between equipment in the network and equipment at a remote location are specified. Equipment may be implemented with additional functions and procedures.

2 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI T1.231-1993; *Telecommunications – In-service Layer 1 digital transmission performance monitoring*

ANSI T1.401-1993; *Telecommunications – Interface between carriers and customer installations – Analog voice-grade switched access lines using loop-start and ground-start signaling.*

ANSI T1.601-1992, *Telecommunications – Integrated Services Digital Network (ISDN) – Basic access interface for use on metallic loops for application on the network side of the NT (Layer 1 specification)*

ANSI/EIA/TIA-571-1991, *Environmental considerations for telephone terminals*

ANSI/EIA RS-422A-1978, *Electrical characteristics of balanced voltage digital interface circuits, 1978*

IEEE Standard 455-1985, *Test procedures for measuring longitudinal balance of telephone equipment operating in the voice band* [1)]

Technical Report No. 28, *A Technical Report on High-bit rate digital subscriber lines,* Committee T1-Telecommunications, February 1994[2)]

[1)] Available from IEEE, 445 Hoes Lane, Piscataway, NJ 08855-1331.

[2)] Available from Alliance for Telecommunications Industry Solutions, 1200 G Street, NW, Suite 500, Washington, DC 20005.

3 Definitions, abbreviations, acronyms and symbols

3.1 Definitions

3.1.1 aggregate data rate: data rate transmitted by an ADSL system in any one direction; it includes both net data rate and data rate overhead used by the system for crc, eoc, synchronization of the various data streams, and fixed indicator bits for OAM; it does not include FEC redundancy.

3.1.2 bearer channel: a user data stream of a specified data rate that is transported transparently by an ADSL system, and carries a bearer service; sometimes abbreviated to bearer.

3.1.3 bearer service: the transport of data at a certain rate without regard to its content, structure, or protocol.

3.1.4 bridged taps: sections of unterminated twisted-pair cable connected in parallel across the cable under consideration.

3.1.5 Category I: a default set of requirements that shall be met by all compliant equipment.

3.1.6 Category II: an enhanced set of requirements that may be met by the provision of certain options.

3.1.7 channelization: allocation of the net data rate to bearer channels.

3.1.8 downstream : ATU-C to ATU-R direction.

3.1.9 loading coils: inductors placed in series with the cable at regular intervals in order to improve the voice-band response.

3.1.10 net data rate: total data rate that is available to user data in any one direction; for the downstream direction this is the sum of the net simplex and duplex data rates.

3.1.11 splitter: a low-pass/high-pass pair of filters that separate high (ADSL) and low (POTS) frequency signals.

3.1.12 transport class: the set of bearer channel data rates and multiplex configurations that may be simultaneously transported on a given loop, based on the maximum aggregate data rate supported by that loop.

3.1.13 upstream: ATU-R to ATU-C direction

3.2 Abbreviations, acronyms and symbols

ADC	analog to digital converter
ADSL	asymmetric digital subscriber line
AEX	byte inserted in the transmitted ADSL frame structure to provide synchronization capacity that is shared among ASX channels
AGC	automatic gain control
aoc	ADSL overhead control channel
AS0 – 3	downstream simplex sub-channel designators
ASX	any one of the simplex channels AS0 to AS3
ATM	asynchronous transfer mode
ATU-C	ADSL transceiver unit, central office end
ATU-R	ADSL transceiver unit, remote terminal end
B_F	the number of bytes in a data stream allocated to the fast (i.e., non-interleaved) buffer

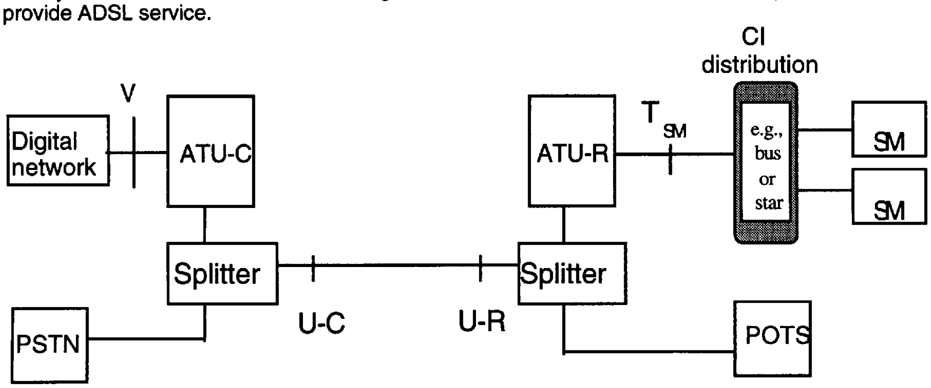
B_I	the number of bytes in a data stream allocated to the interleaved buffer
BRA	basic rate access
CI	customer installation
CO	central office
CSA	carrier serving area
CSA loops	a set of loops within the CSA that are defined by T1 technical report TR-028–1994
crc-8f	cyclic redundancy check using CRC-8 code – fast data
crc-8i	cyclic redundancy check using CRC-8 code – interleaved data
DAC	digital to analog converter
dBm	dB milliwatt; 0 dBm = 1 milliwatt
DMT:	discrete multitone
DSL	digital subscriber line
EC	echo canceling
eoc	embedded operations channel
ERL	echo return loss, as defined by IEEE Std 743-1984
es	errored second
FDM	frequency-division multiplexing
febe-f	far-end block error count – fast data
febe-i	far-end block error count – interleaved data
fecc-f	forward error correction count – fast data
fecc-i	forward error correction count – interleaved data
FEC:	forward error correction
FEXT	far-end cross talk
HDSL	high-rate digital subscriber line
ib0 – 23	indicator Bit(s)
ID code	vendor identification code
IDFT	inverse discrete fourier transform
ISDN	Integrated Services Digital Network
ISDN – BRA	ISDN basic rate access
kbit/s	kilo bits per second
LEX	byte inserted in the transmitted ADSL frame structure to provide synchronization capacity that is shared among LSX and ASX channels
lof	loss of frame
lopr	loss of power
los	loss of signal
LS0 – 2	duplex sub-channel designators
ms	millisecond
NI	network interface
$N_{m,f}$	number of bytes in a fast mux data frame
$N_{m,i}$	number of bytes in an interleaved mux data frame
NEXT	near-end cross talk
OAM	operations, administration and maintenance
OSI	open systems interconnection (7 layer model)
POTS	plain old telephone service (also known as message telecommunications service, MTS)
PRD	pseudo-random downstream
PRU	pseudo-random upstream
PSD	power spectral density
PSTN	public switched telephone network
PRBS	pseudo-random bit sequence
P_{dsf}	number of FEC parity bytes for fast buffer
P_{dsi}	number of FEC parity bytes for interleaved buffer
QAM	quadrature amplitude modulation
rdi	remote defect indication
RT	remote terminal
sc0 – 7	synchronization control bit(s)
sef	severely errored frame
sefs	severely errored frame second
SINAD	signal-to-noise plus distortion (ratio)
SM	service module

SONET	synchronous optical network
SRL	singing return loss, as defined by IEEE Std 743-1984
SRL low	SRL in a band from approximately 260 to 500 Hz
SRL high	SRL in a band from approximately 2200 to 3400 Hz
STM	synchronous transfer mode
T-SM	interface(s) between ATU-R and SM(s)
U-C:	loop interface – central office end
U-R	loop interface – remote terminal end
VDT	video dial tone
V	logical interface between ATU-C and a digital network element such as one or
more	switching systems
VIP	video information provider
4QAM	4-point QAM (i.e., two bits per symbol)
$\oplus$:	exclusive-or; modulo-2 addition

4 Reference models

4.1 System reference model

The system reference model shown in figure 1 illustrates the functional blocks required to provide ADSL service.



NOTES

1 The V interface is defined in terms of logical functions; not physical.

2 The V interface may consist of interface(s) to one or more switching systems.

3 Implementation of the V and T_{SM} interfaces is optional when interfacing elements are integrated into a common element.

4 The splitter function may be integrated into the ATU.

5 A digital carrier facility (e.g., SONET extension) may be interposed at the V interface when the ATU-C is located at a remote site.

6 The nature of the CI distribution (e.g., bus or star, type of media) is for further study.

7 More than one type of T_{SM} interface may be defined, and more than one type of T-sm interface may be provided from an ATU-R.

8 Due to the asymmetry of the signals on the line, the transmitted signals shall be distinctly specified at the U-R and U-C reference points.

9 A future issue of this standard may deal with CI distribution requirements.

Figure 1 – ADSL functional reference model

4.2 ATU-C transmitter reference model

Figure 2 is a block diagram of an ADSL Transceiver Unit-Central office (ATU-C) transmitter showing the functional blocks and interfaces that are referenced in the following clauses.

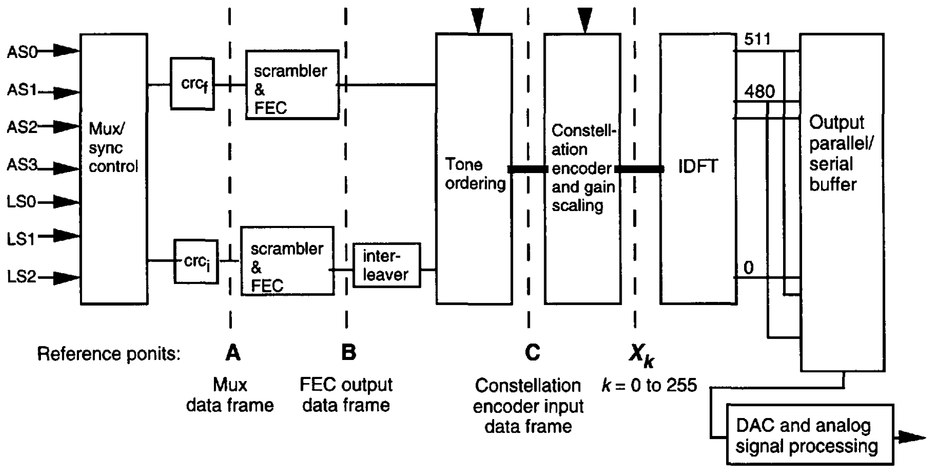


Figure 2 – ATU-C transmitter reference diagram

4.3 ATU-R transmitter reference model

Figure 3 is a block diagram of an ATU-R transmitter showing the functional blocks and interfaces that are referenced in the following clauses.

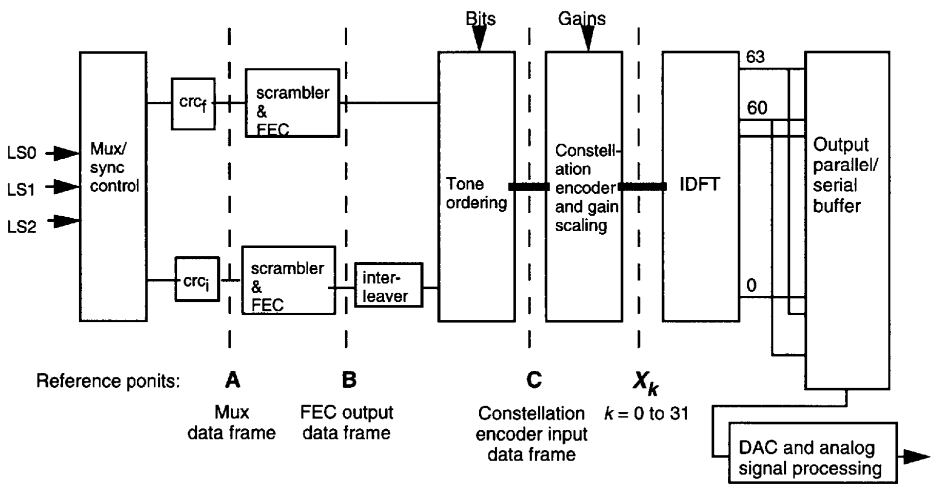


Figure 3 – ATU-R transmitter reference diagram

5 Transport capacity

An ADSL system may transport up to seven bearer channels (bearers) simultaneously:
- up to four independent downstream simplex bearers (unidirectional downstream);
- up to three duplex bearers (bi-directional, downstream and upstream).

The three duplex bearers may alternatively be configured as independent unidirectional simplex bearers, and the rates of the bearers in the two directions (downstream and upstream) do not need to match.

All bearer channel data rates can be programmed in any combination of multiples of 32 kbit/s. Other data rates (non-integer multiples of 32 kbit/s) can also be supported, but will be limited by the ADSL system's available capacity for synchronization (see notes 1 and 2).

Four transport classes are defined for the downstream simplex bearers based on multiples of 1.536 Mbit/s up to 6.144 Mbit/s. Data rates are also defined for duplex bearers to carry a control channel and ISDN channels (basic rate and 384 kbit/s). The ADSL data multiplexing format is flexible enough to allow other transport data rates, such as channelizations based on existing 1.544 or 2.048 Mbit/s formats, and to allow definition of other channelizations in the future in order to accommodate evolving Synchronous or Asynchronous Transfer Modes (STM or ATM) network formats (singly or in combination).

The maximum net data rate transport capacity of an ADSL system will depend on the characteristics of the loop on which the system is deployed and on certain configurable options that affect overhead (see note 3).

Each bearer channel shall be individually assigned to an ADSL sub-channel for transport, and the ADSL sub-channel rate shall be configured during the initialization and training procedure to match the bearer rate.

The transport capacity of an ADSL system per se is defined only as that of the high-speed data streams. When, however, an ADSL system is installed on a line that also carries POTS signals the overall capacity is that of POTS plus ADSL (see clauses 8 and 10 for details on POTS related requirements).

NOTES

1 Part of the ADSL system overhead is shared among the bearer channels for synchronization. The remainder of each channel's data rate that exceeds a multiple of 32 kbit/s shall be transported in this shared overhead.

2 The rates for the downstream simplex bearer channels are based on unframed 1.536 Mbit/s structures in order to be consistent with the expected evolution of network switching. ADSL deployments may need to interwork with DS1 (1.544 Mbit/s) data. The ADSL system overhead and data synchronization (see 6.2.2) provides enough capacity to support the framed DS1 data streams transparently (i.e., the entire DS1 signal is passed through the ADSL transmission path without interpretation or removal of the framing bits and other overhead).

3 One part of the ADSL initialization and training sequence estimates the loop characteristics to determine whether the number of bytes per Discrete MultiTone (DMT) frame required for the requested configuration's aggregate data rate can be transmitted across the given loop. The net data rate is then the aggregate data rate minus ADSL system overhead. Part of the ADSL system overhead is dependent on the configurable options, such as allocation of user data streams to interleaving or non-interleaving data buffers within the ADSL frame (discussed in 6.2, 6.4.2, 7.2, and 7.4.2), and part of it is fixed.

5.1 Simplex bearers

Simplex bearers in the downstream direction are specified herein; the use of upstream simplex bearers is for further study.

5.1.1 Data rates for downstream simplex bearers based on multiples of 1.536 Mbit/s

The default data rates for the four possible simplex bearer channels that may be transported downstream over an ADSL system are

- 1.536 Mbit/s;
- 3.072 Mbit/s;
- 4.608 Mbit/s;
- 6.144 Mbit/s.

The ADSL system may use up to four sub-channels, named AS0, AS1, AS2, and AS3, to transport the downstream simplex bearer channels. An ADSL sub-channel's rate shall match the rate of the bearer channel that it transports, subject to the restrictions given in table 1.

Table 1 – ADSL sub-channel rate restrictions for default bearer rates

Sub-channel designations	Sub-channel data rate	Allowed values of n_x
AS0	$n_0 \times 1.536$ Mbit/s	$n_0 = 0, 1, 2, 3,$ or 4
AS1	$n_1 \times 1.536$ Mbit/s	$n_1 = 0, 1, 2,$ or 3
AS2	$n_2 \times 1.536$ Mbit/s	$n_2 = 0, 1,$ or 2
AS3	$n_3 \times 1.536$ Mbit/s	$n_3 = 0$ or 1
NOTE – Rates equivalent to multiple DS1s are also supported.		

The maximum number of sub-channels that may be active at any given time and the maximum number of bearer channels that can be transported simultaneously by an ADSL system will depend on the transport class (as described in 5.1.1.1 through 5.1.1.4) that can be supported by the specific loop and on the configuration of the active sub-channels. Switching on demand among the configurations allowed by a given transport class is for further study.

To comply with this standard the AS0 sub-channel and at least transport classes 1 (5.1.1.1) and 4 (5.1.1.4) shall be supported. Support of sub-channels AS1, AS2, AS3, and transport classes 2, 3, and 2M is optional.

5.1.1.1 Downstream simplex bearer configurations for transport class 1 (shortest range, highest capacity)

The net simplex bearer capacity on transport class 1 is 6.144 Mbit/s, which may be composed of any combination of one to four bearer channels with $n \times 1.536$ Mbit/s rates. Systems shall support at least a 6.144 Mbit/s bearer channel on sub-channel AS0. The following transport class 1 configurations are optional:

- one 4.608 Mbit/s bearer channel and one 1.536 Mbit/s bearer channel;
- two 3.072 Mbit/s bearer channels;
- one 3.072 Mbit/s bearer channel and two 1.536 Mbit/s bearer channels;
- four 1.536 Mbit/s bearer channels.

5.1.1.2 Downstream simplex bearer configurations for optional transport class 2

The net simplex bearer capacity on transport class 2 is 4.608 Mbit/s, which may be composed of any combination of one to three bearer channels with $n \times 1.536$ Mbit/s rates. Systems, at their option, may provide any and all bearer rates. Transport class 2 configuration options are:

- one 4.608 Mbit/s bearer channel;
- one 3.072 Mbit/s bearer channel and one 1.536 Mbit/s bearer channel;
- three 1.536 Mbit/s bearer channels.

ADSL sub-channel AS3 shall not be used in this configuration.

5.1.1.3 Downstream simplex bearer configurations for optional transport class 3

The net simplex bearer capacity on transport class 3 is 3.072 Mbit/s, which may be composed of one or two bearer channels with $n \times 1.536$ Mbit/s rates. Systems, at their option, may provide either or both bearer rates. Transport class 3 configuration options are:

- one 3.072 Mbit/s bearer channel;
- two 1.536 Mbit/s bearer channels.

ADSL sub-channels AS2 and AS3 shall not be used in this configuration.

5.1.1.4 Downstream simplex bearer configurations for transport class 4 (longest range, lowest capacity)

Only one downstream simplex bearer option can be supported in transport class 4. The bearer channel capacity of one 1.536 Mbit/s bearer channel shall be transported on sub-channel AS0.

5.1.2 Optional data rates for downstream simplex bearers based on multiples of 2.048 Mbit/s

ADSL equipment may include channelization options other than those defined in 5.1.1. For example, the rate structure outlined in this subclause accommodates a digital hierarchy based on multiples of 2.048 Mbit/s.

This 2.048 Mbit/s rate structure is optional, both in implementation of equipment and in the provision of service. Equipment or service implementation at the 1.536 Mbit/s rate (or multiples) but not the 2.048 Mbit/s rate would still fully conform to the standard. Information related to 2.048 Mbit/s applications may be found in annex H.

Bearer channels based on 2.048 Mbit/s that may optionally be transported downstream over an ADSL system are

- 2.048 Mbit/s;
- 4.096 Mbit/s;
- 6.144 Mbit/s.

The entire framed 2.048 Mbit/s structure is treated as a bearer data stream; the use of a lower payload rate is for further study.

An ADSL system supporting these options may use up to three of the downstream simplex sub-channels, AS0, AS1, and AS2, to transport the bearer channels. An ADSL sub-channel's rate shall match the rate of the bearer channel that it transports, subject to the restrictions given in table 2.

Table 2 – ADSL Sub-channel rate restrictions 2.048 Mbit/s (optional)

Sub-channel designations	Sub-channel data rate	Allowable values of n_x
AS0	$n_0 \times 2.048$ Mbit/s (optional)	$n_0 = 0, 1, 2,$ or 3
AS1	$n_1 \times 2.048$ Mbit/s (optional)	$n_1 = 0, 1,$ or 2
AS2	$n_2 \times 2.048$ Mbit/s (optional)	$n_2 = 0$ or 1

The maximum number of sub-channels that may be active at any given time, and the maximum number of bearer channels that can be transported simultaneously by an ADSL system depends on the transport class (as described in 5.1.2.1 through 5.1.2.3) that can be supported by the specific loop on which the system is deployed, and the configuration of the active sub-channels.

5.1.2.1 Downstream simplex bearer configurations for optional transport class 2M-1

The simplex bearer capacity on the optional transport class 2M-1 is 6.144 Mbit/s, which may be composed of any combination of one to three bearer channels with $n \times 2.048$ Mbit/s rates. Systems, at their option, may provide any and all bearer rates. Transport class 2M-1 configuration options are:

- one 6.144 Mbit/s bearer channel;
- one 4.096 Mbit/s bearer channel and one 2.048 Mbit/s bearer channel;
- three 2.048 Mbit/s bearer channels.

5.1.2.2 Downstream simplex bearer configurations for optional transport class 2M-2

The combined simplex bearer capacity on optional transport class 2M-2 is 4.096 Mbit/s, which may be composed of one or two bearer channels with $n \times 2.048$ Mbit/s rates. Systems, at their option, may provide either or both bearer rates. Transport class 2M-2 configuration options are:

- one 4.096 Mbit/s bearer channel;
- two 2.048 Mbit/s bearer channels.

ADSL sub-channel AS2 shall not be used in this configuration.

5.1.2.3 Downstream simplex bearer configurations for optional transport class 2M-3

Only one downstream simplex bearer option –2.048 Mbit/s transported on ADSL sub-channel AS0 – can be supported in transport class 2M-3.

5.1.3 Options for transporting downstream simplex ATM data streams

ADSL equipment may also provide the capability to transport ATM data as a single downstream simplex data stream.

If this capability is provided the ADSL bearer channel rates shall be based on
- $n \times 1.536$ Mbit/s user data content, where $n = 1 - 4$;
- AAL1 cell format (ATM Adaption Layer 1), in which each 53-byte ATM cell transports 47 bytes of user data, yielding ATM data cell bit rates of $n \times 1.536$ Mbit/s $\times$ 53/47;
- rounding the ATM data cell bit rate up to the nearest integer multiple of 32 kbit/s by insertion of idle cells (and possibly OAM cells as suggested by CCITT Rec. I.610) by an ATM cell processor on the network side of the V-interface.

Only the ADSL downstream simplex sub-channel AS0 shall be used, resulting in a single configuration option for the downstream simplex bearer, and its rate depends on the transport class as specified in table 3.

Table 3 – Downstream ATM data cell bit rates

Transport class	Bearer channel rate	ATM data cell bit rate
1	6.944 Mbit/s	6.928340 Mbit/s
2	5.216 Mbit/s	5.196255 Mbit/s
3	3.488 Mbit/s	3.464170 Mbit/s
4	1.760 Mbit/s	1.732085 Mbit/s

5.1.4 Upstream simplex bearers

Upstream simplex bearers are for further study.

5.2 Duplex bearers

Up to three duplex bearer channels may be transported simultaneously by an ADSL system. One of these is the mandatory control (C) channel. Data rates for this channel, which shall always be active, are specified in 5.2.1.

Depending on the maximum aggregate rate that can be supported on the specific loop and on the options implemented, specific limitations apply to the other two optional duplex ADSL sub-channels. Only certain allowed combinations of these may be active in any given configuration; these are defined in 5.2.2.

5.2.1 Data rates for the control channel (mandatory duplex channel)

The C channel shall transport CI to CI (e.g., control of services) and CI-to-network signaling (i.e., call setup and selection of services) for the downstream simplex bearer services, and it may also transport some or all of the CI-to-network signaling for the optional duplex services. For transport classes 4 and 2M-3 the C channel shall operate at 16 kbit/s, and be transported within the ADSL synchronization overhead (see 6.2); for all other classes it shall operate at 64 kbit/s, and be transported on ADSL sub-channel LS0.

5.2.2 Data rates for the optional duplex bearer channels

Two optional duplex bearer channels may be transparently transported by an ADSL system, depending on the service offered by the network provider.

If these bearer channels are transported the sub-channel assignments and data rates shall be:

- ADSL sub-channel LS1 at 160 kbit/s;
- ADSL sub-channel LS2 at 384 kbit/s or 576 kbit/s.

The duplex options for the four transport classes are given in table 4.

Table 4 – Maximum optional duplex bearer channels supported by transport class

Transport class	Optional duplex bearers that may be transported (note 1)	Active ADSL sub-channels
1 or 2M-1 (minimum range)	Configuration 1: 160 kbit/s + 384 kbit/s; Configuration 2: 576 kbit/s only	LS1, LS2 LS2 only
2, 3 or 2M-2 (mid range)	Configuration 1: 160 kbit/s only Configuration 2: 384 kbit/s only (see note 2)	LS1 only LS2 only
4 or 2M-3 (maximum range)	160 kbit/s only	LS1 only

NOTES

1 When the 160 kbit/s optional duplex bearer is used to transport ISDN BRA, all signaling associated with the ISDN BRA (160 kbit/s) is carried by the D channel of the 2B + D signal embedded in the 160 kbit/s. Signaling for the 576 kbit/s, 384 kbit/s and non-ISDN 160 kbit/s duplex bearers may be included in the C channel, which is shared with the signaling for the downstream simplex bearer channels.

2 Whether transport classes 2, 3, or 2M-2 should support the 576 kbit/s optional duplex bearer is for further study.

5.2.3 Options for transporting duplex ATM data streams on the optional duplex channel LS2

ADSL equipment providers may also at their discretion, provide the capability to transport an ATM cell stream on the optional duplex LS2 channel.

If this duplex ATM transport capability is provided, the bearer channel rates shown in table 5 shall be based on:

- 384 kbit/s or 576 kbit/s user data content;
- AAL1 or AAL5 cell format (ATM Adaption Layer 1: each 53-byte ATM cell transports 47 bytes of user data) yielding ATM data cell bit rates of 384 × (53/47) kbit/s or 576 × (53/47) kbit/s;
- rounding the ATM data cell bit rate to the nearest integer multiple of 32 kbit/s by insertion of idle cells (and possibly OAM cells as suggested by CCITT Recommendation I.610) by an ATM cell processor on the network side of the V-interface and on the service module side of the T-interface.

Table 5 – Optional duplex ATM data cell bit rates for LS2

ADSL optional LS2 channel rate	ATM data cell bit rate
448 kbit/s	443.0213 kbit/s
672 kbit/s	649.5320 kbit/s

– The configuration options for each transport class are based on the default (non-ATM) data rates. Use of the optional ATM rates may reduce the loop reach or limit the configuration options possible on a given loop.

5.3 Combined options

5.3.1 Options for bearer channel rates based on downstream multiples of 1.536 Mbit/s

As specified in 5.1 and 5.2, different ADSL sub-channel and bearer configuration options may be provided for each of the transport classes. Within a given transport class, the allowable downstream simplex bearer and duplex bearer configurations may be treated independently. The net data rates (i.e., maximum bearer capacities) based on multiples of 1.536 Mbit/s for transport classes 1 and 4 (and for optional classes 2 and 3 if they are provided), shall be as summarized in table 6.

Table 6 – Bearer channel options by transport class for bearer rates based on downstream multiples of 1.536 Mbit/s

Transport class:	1	2	3	4
Downstream simplex bearers:				
Maximum capacity	6.144 Mbit/s	4.608 Mbit/s	3.072 Mbit/s	1.536 Mbit/s
Bearer channel options	1.536 Mbit/s, 3.072 Mbit/s, 4.608 Mbit/s, 6.144 Mbit/s	1.536 Mbit/s, 3.072 Mbit/s, 4.608 Mbit/s	1.536 Mbit/s, 3.072 Mbit/s	1.536 Mbit/s
Maximum active sub-channels	4 (AS0,AS1, AS2,AS3)	3 (AS0, AS1, AS2)	2 (AS0, AS1)	1 (AS0 only)
Duplex bearers:				
Maximum capacity	640 kbit/s	608 kbit/s	608 kbit/s	176 kbit/s
Bearer channel options	576 kbit/s, 384 kbit/s, 160 kbit/s, C (64 kbit/s)	see note 384 kbit/s, 160 kbit/s, C (64 kbit/s)	see note 384 kbit/s, 160 kbit/s, C (64 kbit/s)	160 kbit/s, C (16 kbit/s)
Max. active sub-channels	3 (LS0, LS1, LS2)	2 (LS0,LS1) or (LS0, LS2)	2 (LS0,LS1) or (LS0, LS2)	2 (LS0,LS1)
NOTE – Whether transport classes 2 or 3 should support the 576 kbit/s optional duplex bearer is for further study.				

The configuration shall be specified by the B_F and B_I parameters (described in 6.2, 7.2, and 12.8) for each bearer channel.

5.3.2 Options for bearer channel rates based on downstream multiples of 2.048 Mbit/s

The maximum bearer capacities for the three possible transport classes for the optional bearer rates based on 2.048 Mbit/s are summarized in table 7.

Table 7 – Bearer channel options by transport class – optional bearer rates based on downstream multiples of 2.048 Mbit/s

Transport class:	2M-1	2M-2	2M-3
Downstream simplex bearers			
Maximum capacity	6.144 Mbit/s	4.096 Mbit/s	2.048 Mbit/s
Bearer channel options	2.048 Mbit/s, 4.096 Mbit/s, 6.144 Mbit/s	2.048 Mbit/s, 4.096 Mbit/s	2.048 Mbit/s
Max. active sub-channels	3 (AS0,AS1,AS2)	2 (AS0,AS1)	1 (AS0 only)
Duplex bearers			
Maximum capacity	640 kbit/s	608 kbit/s	176 kbit/s
Bearer channel options	576 kbit/s, 384 kbit/s, 160 kbit/s, C (64 kbit/s)	see note 384 kbit/s, 160 kbit/s, C (64 kbit/s)	160 kbit/s, C (16 kbit/s)
Max. active sub-channels	3 (LS0, LS1, LS2)	2 (LS0,LS1 or (LS0, LS2)	2 (LS0, LS1)
NOTE – Whether transport class 2M-2 should support the 576 kbit/s optional duplex bearer is for further study.			

The configuration shall be specified by the B_F and B_I parameters (described in 6.2, 7.2, and 12.8) for each bearer channel.

5.3.3 Options for bearer channel options transporting ATM cell streams

For optional bearer rates transporting an ATM cell stream in the downstream simplex channel, up to four transport classes can be defined. These are roughly equivalent to the default bearer transport classes. Only one configuration option is expected to be supported by each transport class: that of the single downstream simplex channel carrying the ATM data and the single mandatory duplex channel to carry signaling and service control traffic. Equipment and service providers may optionally provide duplex bearers over loops that can support a higher aggregate ADSL rate than those representative of the transport classes. The optional ATM bearer rates are summarized in table 8.

Table 8 – Bearer channel options by transport class for optional ATM bearer rates

Transport class:	1	2	3	4
Downstream simplex bearers				
Aggregate ATM data cell bit rate	6.928340 Mbit/s	5.196255 Mbit/s	3.464170 Mbit/s	1.732085 Mbit/s
Bearer channel rate (see note 1)	6.944 Mbit/s	5.216 Mbit/s	3.488 Mbit/s	1.760 Mbit/s
Maximum active subchannels	1 (AS0 only)	1 (AS0 only)	1 (AS0 only)	1 (AS0 only)
Duplex bearers				
Maximum capacity	64 kbit/s	64 kbit/s	64 kbit/s	16 kbit/s
Bearer channel options	C (64 kbit/s)	C (64 kbit/s)	C (64 kbit/s)	C (16 kbit/s)
Maximum active subchannels	1 (LS0)	1 (LS0)	1 (LS0)	1 (LS0) (see note 2)

NOTES

1 The bearer channel rate is equal to the ATM data cell bit rate rounded up to the nearest integer multiple of 32 kbit/s (an ATM cell processor on the network side of the V-interface performs the rate adjustment by inserting idle cells).

2 The 16 kbit/s C channel is carried entirely within the synchronization overhead as described in 6.2; the LS0 sub-channel does not appear as a separate byte within the ADSL frame.

5.4 ADSL system overheads and aggregate bit rates

The aggregate bit rate transmitted by the ADSL system shall include capacity for the following:

- the transported simplex bearer channels;
- the transported duplex bearer channels;
- ADSL system overhead, which includes:
  - capacity for synchronization of the simplex and duplex bearers;
  - synchronization control for the bearers transported with interleaving delay (interleave data buffer) and with no interleaving delay ("fast", or low-latency, data buffer);
  - an ADSL embedded operations channel, eoc (see note);
  - an ADSL overhead control channel, aoc (for on-line adaptation and reconfiguration, as described in clause 13);
  - crc check bytes;
  - fixed indicator bits for OAM (Operations, Administration and Maintenance);
  - FEC redundancy bytes.

NOTES

1 For the downstream simplex bearer rates based on 1.536 Mbit/s, the maximum capacity available to eoc is approximately 23.7 kbit/s for transport classes 1, 2, and 3, and approximately10.7 kbit/s for transport class 4. Actual eoc capacities will depend on the bearer channel rates and the data synchronization implementation.

2 In addition to the digital transport listed throughout this clause, the ADSL shall also permit the transport of POTS as a baseband analog signal.

The organization of all the above data streams into ADSL frames and ADSL superframes shall be as given in 6.2 for the downstream data transmitted and in 7.2 for the upstream data.

The internal overhead channels and their rates shall be as shown in table 9.

Table 9 – Internal overhead channel functions and rates

	Downstream rate maximum / minimum / default		**Upstream rate maximum / minimum / default**	
	Transport classes 1, 2, 3, 2M-1, or 2M-2 (minimum and mid range loops)	Transport class 4 or 2M-3 (maximum range loop)	Transport classes 1, 2, 3, 2M-1, or 2M-2 (minimum and mid range loops)	Transport class 4 or 2M-3 (maximum range loop)
Synchronization capacity, shared among all bearers (see note 2)	128 / 64 / 96 kbit/s	96 / 64 / 96 kbit/s (see note 3)	64 / 32 / 64 kbit/s	64 / 32 / 64 kbit/s
Synchronization control and crc, interleave buffer	32 kbit/s	32 kbit/s	32 kbit/s	32 kbit/s
Synchronization control and crc, fast buffer, plus eoc and indicator bits	32 kbit/s	32 kbit/s	32 kbit/s	32 kbit/s
Total	192 / 128 / 160 kbit/s	160 / 128 / 160 kbit/s	128 / 96 / 128 kbit/s	128 / 96 / 128 kbit/s

NOTES

1 The overhead required for FEC is not shown in this table.

2 The shared synchronization capacity includes 32 kbit/s shared among duplex bearers within the interleave buffer, 32 kbit/s shared among bearers within the fast buffer, an additional 32 kbit/s shared with downstream simplex bearers within the interleave buffer, and an additional 32 kbit/s shared with downstream simplex bearers within the fast buffer. The maximum rate occurs when at least one downstream simplex bearer is allocated to each type of buffer; the minimum rate occurs when all bearers are allocated to one buffer type. Default rate allocates bearers according to defaults described in 6.2 and assumes that all optional duplex bearers are implemented.

3 Only one downstream simplex bearer is available in transport class 4 or 2M-3 (maximum range loops); the 64 kbit/s for synchronization of the simplex bearer to ADSL framing can appear in only one of the ADSL buffers (fast or interleaved).

The aggregate transmitted bit rate will depend on the transport class and implementation of optional duplex channels; components of the aggregate transmitted bit rate are summarized in table 10 for downstream transmission and in table 11 for upstream.

Table 10 – Determination of aggregate downstream bit rate

	1.536 or 2.048 Mbit/s bearers	**Default bearer channels ($n \times$ 1.536 Mbit/s)**			**Optional bearers based on 2.048 Mbit/s** (see note 1)	
	Transport class 1	Transport class 2 (see note 2)	Transport class 3 (see note 2)	Transport class 4	Transport class 2M-2 (see note 2)	Transport class 2M-3
Total downstream simplex bearer capacity	6.144 Mbit/s	4.608 Mbit/s	3.072 Mbit/s	1.536 Mbit/s	4.096 Mbit/s	2.048 Mbit/s
Duplex C channel	64 kbit/s	64 kbit/s	64 kbit/s	(see note 3)	64 kbit/s	(see note 3)
Total for optional duplex bearers	0, 160, 384, 544 , or 576 kbit/s (see note 4)	0, 160, or 384 kbit/s	0, 160, or 384 kbit/s	0 or 160 kbit/s	0, 160, or 384 kbit/s	0 or 160 kbit/s
Total bearer channel capacity	6.208-6.784 Mbit/s	4.672-5.056 Mbit/s	3.136-3.520 Mbit/s	1.536-1.696 Mbit/s (see note 5)	4.160-4.544 Mbit/s	2.048-2.208 Mbit/s (see note 5)
Overhead range (from table 9)	128 – 192 kbit/s	128 – 192 kbit/s	128 – 192 kbit/s	128 – 160 kbit/s	128 – 192 kbit/s	128 – 160 kbit/s
Aggregate rate range (typical)	6.336-6.976 Mbit/s (6.912 Mbit/s)	4.800-5.248 Mbit/s (5.216 Mbit/s)	3.264-3.712 Mbit/s (3.680 Mbit/s)	1.664-1.856 Mbit/s (1.824 Mbit/s)	4.288-4.736 Mbit/s (4.704 Mbit/s)	2.176-2.368 Mbit/s (2.336 Mbit/s)

NOTES

1 The optional transport class 2M-1 for bearers based on 2.048 Mbit/s has the same combined rates as the default transport class 1.

2 If it is determined that transport classes 2, 3, and 2M-2 can support the 576 kbit/s optional duplex bearer, then the maximum total bearer channel capacity and maximum aggregate rate will increase by 32 kbit/s for these classes.

3 The 16 kbit/s duplex C channel is transported entirely within the overhead dedicated to synchronization capacity.

4 544 kbit/s is required when a 160 kbit/s and a 384 kbit/s optional duplex bearer are both included.

5 The duplex C channel is not included in total bearer channel rates for transport classes 4 and 2M-3; it is included in the overhead.

6 The overhead required for FEC is not shown in this table.

Table 11 – Determination of aggregate upstream bit rate

	Transport class 1 or 2M-1	**Transport classes 2, 3 or 2M-2** (see note 1)	**Transport class 4 or 2M-3**
Duplex C channel	64 kbit/s	64 kbit/s	(see note 2)
Total for optional duplex bearers	0, 160, 384, 544, or 576 kbit/s (see note 3)	0, 160, or 384 kbit/s	0 or 160 kbit/s
Total bearer channel capacity	64 – 640 kbit/s	64 – 448 kbit/s	0 – 160 kbit/s
Overhead range (from table 9)	96 – 128 kbit/s	96 – 128 kbit/s	96 – 128 kbit/s
Aggregate rate range (typical)	160 – 768 kbit/s (768 kbit/s)	160 – 576 kbit/s (576 kbit/s)	96 – 288 kbit/s (288 kbit/s)

NOTES

1 If it is determined that transport classes 2, 3, and 2M-2 can support the 576 kbit/s optional duplex bearer, then the maximum total bearer channel capacity and maximum aggregate rate will increase by 32 kbit/s for these classes.

2 For transport classes 4 and 2M-3, the duplex C channel is 16 kbit/s; this is not included in the total bearer channel rates because it is transported entirely within the overhead dedicated to synchronization capacity.

3 544 kbit/s obtained when both optional duplex bearers are included.

4 The overhead required for FEC is not shown in this table.

5.4.1 Aggregate bit rates for transporting ATM cells

The aggregate transmitted bit rate when an ATM data stream is transported depends on the transport class and allocation of channels to interleaved and non-interleaved data buffers (see 6.2). Components of the aggregate transmitted bit rate are summarized in table 12.

Table 12 – Determination of aggregate bit rate for ATM transport
($n \times 1.536$ Mbit/s $\times$ 53/47 optional bearer channels)

Transport class	1	2	3	4
Total assigned downstream simplex bearer capacity	6.944 Mbit/s	5.216 Mbit/s	3.488 Mbit/s	1.760 Mbit/s
Duplex C channel	64 kbit/s	64 kbit/s	64 kbit/s	(see note 1)
Total for Optional Duplex Bearers	0 kbit/s	0 kbit/s	0 kbit/s	0 kbit/s
Total Bearer Channel Capacity	7.008 Mbit/s	5.280 Mbit/s	3.552 Mbit/s	1.760 Mbit/s (see note 1)
Overhead Range (from table 9, see note 2)	128 – 160 kbit/s	128 – 160 kbit/s	128 – 160 kbit/s	128 – 160 kbit/s
Aggregate Rate Range	7.136 to 7.168 Mbit/s	5.408 to 5.440 Mbit/s	3.680 to 3.712 Mbit/s	1.888 to 1.920 Mbit/s

NOTES

1 The duplex C channel is not included in total bearer channel rate for Transport Class 4; it is included in the overhead.

2 Maximum overhead is 160 kbit/s for all transport classes because only one downstream simplex channel is allowed.

5.5 Classification by ATU options

Subclause 15.1 describes a further classification, which ties together transport payload and loop range based upon whether or not certain options available for the ATU transceivers are used. Category I describes loop ranges and transport payloads using a basic transceiver with no options required. Category II describes loop ranges and transport payloads using options for trellis coding, power boost, and echo cancellation.

6 ATU-C functional characteristics

6.1 ATU-C input and output V interfaces

The functional data interfaces at the ATU-C are shown in figure 4. Input interfaces for the high-speed downstream simplex bearer channels are designated AS0 through AS3; input/output interfaces for the duplex bearer channels are designated LS0 through LS2. There may also be a duplex interface for operations, maintenance and control of the ADSL system.

The data rates of the input and output data interfaces at the ATU-C for the default configurations are specified in this clause. The data rate at a given interface shall match the rate of the bearer channel configured to that interface.

The total net bearer capacity that can be transmitted in the downstream direction corresponds to the transport class as described in 5.3; the mix of data rates at the downstream simplex input interfaces shall be limited to a combination whose net bit rate does not exceed the net downstream simplex bearer capacity for the given transport class. Similarly, the rate of the duplex bearer at the LS0 interface and the availability of the LS1 and LS2 options shall correspond to the transport class as discussed in 5.3.

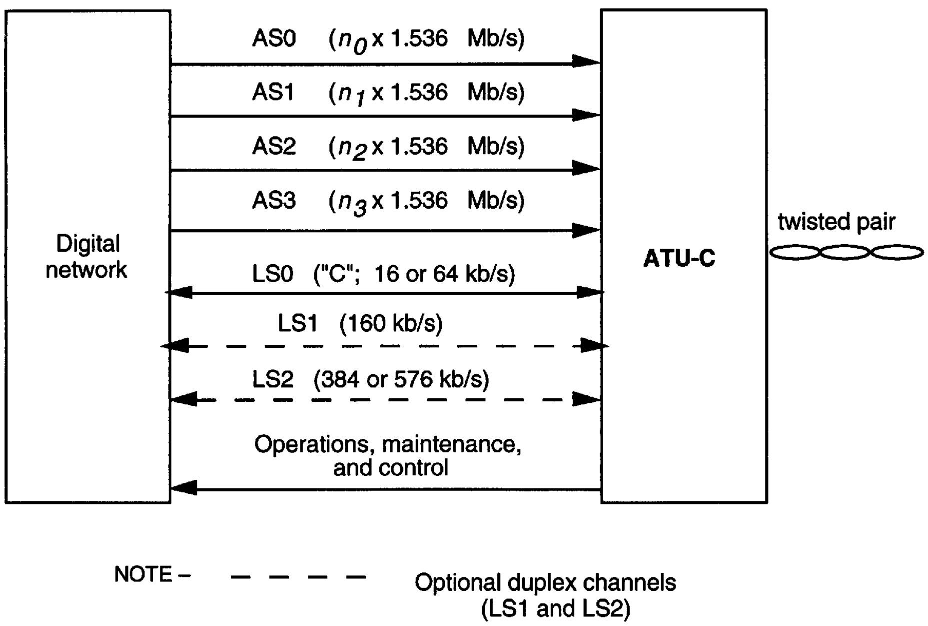


Figure 4 – ATU-C V interfaces (rates for default configuration)

6.1.1 Downstream simplex channels – transmit bit rates

There are four input interfaces at the ATU-C for the high-speed downstream simplex channels based on multiples of 1.536 Mbit/s: AS0, AS1, AS2 and AS3 (ASX in general). The data rates at these interfaces shall be as defined in table 1.

Similarly, there are three interfaces for the optional high-speed downstream simplex channels based on multiples of 2.048 Mbit/s: AS0, AS1, and AS2 (ASX in general). The data rates at these interfaces are defined in table 2.

6.1.2 Transmit and receive bit rates for the duplex channels

Both input and output data interfaces shall be supplied at the ATU-C for the duplex bearers supported by the ADSL system.

NOTE – Two of the duplex channels are optional, as described in 5.2.2; the rate of the third duplex channel depends on the transport class, as defined in 5.2.1.

Table 13 shows the data rates that shall be supported by both the input and output interfaces at the ATU-C for the duplex channels for the default configurations.

Table 13 – Interface data rates for duplex channels (default configurations)

Duplex channel	Data rate
LS0 (see note 1)	16 or 64 kbit/s
LS1 (see note 2)	160 kbit/s
LS2	384 kbit/s or 576 kbit/s
Operations, maintenance, and control	vendor specific

NOTES

1 LS0 is also known as the "C" or control channel. It carries the signaling associated with the ASX data streams and it may also carry some or all of the signaling associated with the other duplex data streams. When LS1 transports ISDN BRA, the signaling for LS1 is contained within the ISDN BRA D channel. If LS1 is used to transport a non-ISDN BRA data stream, then its signaling will also be contained in the C channel.

2 LS1 may be used to carry ISDN BRA. Refer to 6.2.3 for a description of the frame format used within LS1 when it carries this service.

6.1.3 Payload transfer delay

The one-way transfer delay for payload bits in all bearers (simplex and duplex) from the V reference point to the T_{SM} reference point for channels assigned to the fast buffer shall be no more than 2 ms, and for channels assigned to the interleave buffer it shall default to no more than 20 ms. The same requirement applies in the opposite direction, from the T_{SM} reference point to the V reference point.

6.2 Framing

This subclause specifies framing of the downstream signal (ATU-C transmitter). The upstream framing (ATU-R transmitter) is specified in 7.2.

6.2.1 Data symbols

Figure 2 shows a functional block diagram of the ATU-C transmitter with reference points for data framing. Up to four downstream simplex data channels and up to three duplex data channels shall be synchronized to the 4 kHz ADSL DMT symbol rate, and multiplexed into two separate data buffers (fast and interleaved). A cyclic redundancy check (crc), scrambling, and forward error correction (FEC) coding shall be applied to the contents of each buffer separately, and the data from the interleaved buffer shall then be passed through an interleaving function. The two data streams shall then be tone ordered as defined in 6.5, and combined into a data symbol that is input to the constellation encoder. After constellation encoding, the data shall be modulated to produce an analog signal for transmission across the customer loop.

A bit-level framing pattern shall not be inserted into the data symbols of the frame or superframe structure. DMT symbol, or frame, boundaries are delineated by the cyclic prefix inserted by the modulator (see 6.10). Superframe boundaries are determined by the synchronization symbol, which shall also be inserted by the modulator, and which carries no user data (see 6.9.3).

Because of the addition of FEC redundancy bytes and data interleaving, the data symbols (i.e., bit-level data prior to constellation encoding) have different structural appearance at the three reference points through the transmitter. As shown in figure 2, the reference points for which data framing will be described in the following subclauses are

- *A (Mux data frame):* the multiplexed, synchronized data after the crc has been inserted (synchronization is described in 6.2.2, crc is specified in 6.2.1.3). Mux data frames shall be generated at a nominal 4 kHz rate (i.e., each 250 µsec).
- *B (FEC output data frame):* the data frame generated at the output of the FEC encoder at the DMT symbol rate, where an FEC block may span more than one DMT symbol period.
- *C (constellation encoder input data frame):* the data frame presented to the constellation coder.

6.2.1.1 Superframe structure

ADSL uses the superframe structure shown in figure 5. Each superframe is composed of 68 ADSL data frames, numbered from 0 to 67, which shall be encoded and modulated into DMT symbols, followed by a synchronization symbol, which carries no user or overhead bit-level data and is inserted by the modulator (see 6.9.3) only to establish superframe boundaries. From the bit-level and user data perspective, the DMT symbol rate is 4000 baud (period = 250 µsec), but in order to allow for the insertion of the sync symbol the transmitted DMT symbol rate shall be 69/68 × 4000 baud. Each data frame within the superframe contains data from the fast buffer and the interleaved buffer. The size of each buffer depends on the assignment of bearer channels made during initialization (see 6.2.1 and 12.8.4). (On-line reassignment of bearer channels is for further study.)

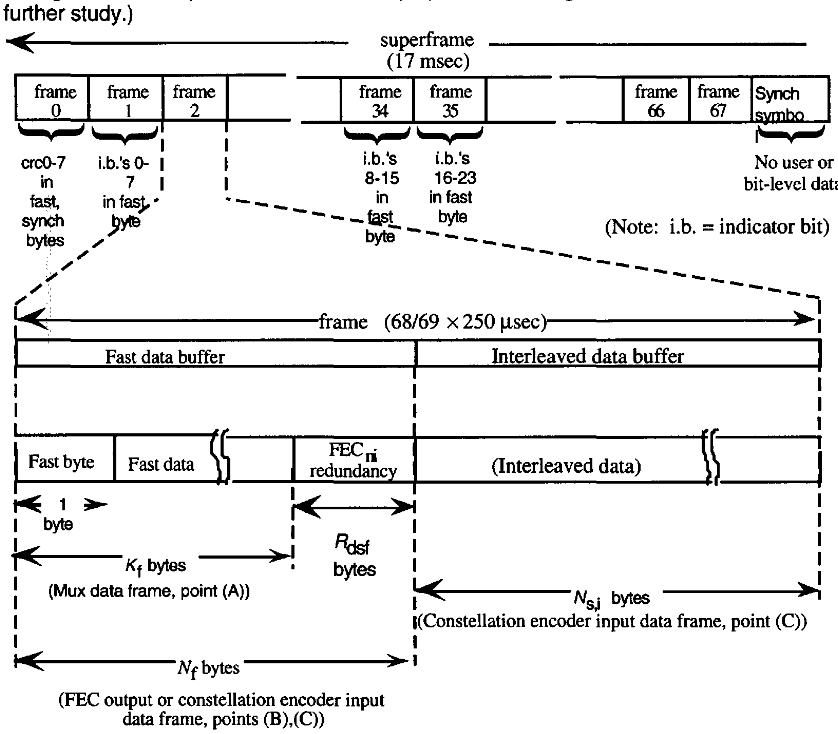


Figure 5 – ADSL superframe structure – ATU-C transmitter

Eight bits per ADSL superframe shall be reserved for the crc on the fast data buffer (crc0-crc7), and 24 indicator bits (ib0-ib23) shall be assigned for OAM functions. As shown in *figures 5 and 6*, the "fast" byte of the fast data buffer carries the crc check bits in frame 0 and the fixed overhead bit assignments in frames 1, 34, and 35. The "fast" byte in other frames is assigned in even-/odd-frame pairs to either the eoc or to synchronization control of the bearer channels assigned to the fast buffer.

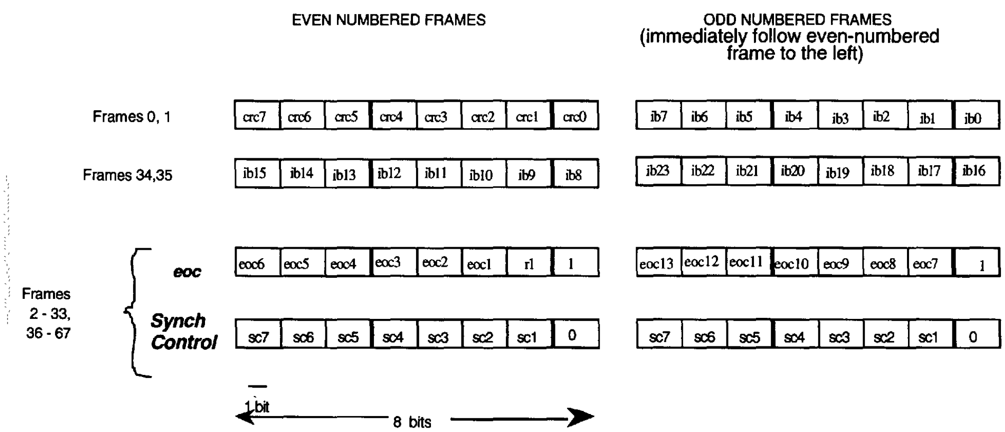


Figure 6 – "Fast" byte format – ATU-C transmitter – fast data buffer

The indicator bits are defined in table 14.

Table 14 – Definition of indicator bits, ATU-C transmitter
(fast data buffer, downstream direction)

Indicator bit	**Definition**
ib0 – ib7	reserved for future use
ib8	febe-i
ib9	fecc-i
ib10	febe-ni
ib11	fecc-ni
ib12	los
ib13	rdi
ib14 – ib23	reserved for future use
NOTE – See clause 11 for definitions of the bits and their use.	

If bit 0 of the "fast" byte in an even-numbered frame (other than frames 0 and 34) is "1", then the "fast" byte of that frame and the odd-numbered frame that immediately follows is used to carry a 13-bit "eoc frame", which is defined in table 15, and on additional bit, r1, which is reserved for future use (set to 1 until assigned otherwise).

Table 15 – eoc frame structure

Bit designation	eoc bit allocation
eoc1, eoc2	Address (11 = ATU-C, 00 = ATU-R, 01 and 10 reserved)
eoc3	Data/message indicator bit: "0" = information field contains op code for ADSL eoc message, "1" = information field contains binary or ASCII data.
eoc4	Odd ("1") / Even ("0") byte indicator for multibyte transmission in data read or write mode
eoc5	Autonomous ATU-R message indicator bit (see note): "0" = autonomous ATU-R message, "1" = ATU-R response to current eoc protocol state.
eoc6 – eoc13	Information field.

NOTE – The only autonomous message currently defined for the ATU-R is the "dying gasp" (11.1.4.4). Other uses of the eoc5 bit are for further study.

The eoc protocol and message formats are described in 11.1.

Bit 0 of the "fast" byte in an even-numbered frame (other than frames 0 and 34) shall be set to "0", to indicate that the "fast" bytes of that frame and the odd-numbered frame that immediately follows are used for synchronization control within their respective frames (the "fast" byte format for synch control is described in 6.2.2.1).

Eight bits per ADSL superframe shall be used for the crc on the interleaved data buffer (crc0 – crc7). As shown in figures 6 and 7, the "synch" byte of the interleaved data buffer carries the crc check bits for the previous superframe in frame 0. In all other frames (1 through 67), the "synch" byte shall be used for synchronization control of the bearer channels assigned to the interleaved data buffer, or to carry an ADSL overhead control (aoc) channel. When any bearer data streams appear in the interleave buffer, then the aoc data shall be carried in the LEX byte, and the "synch" byte shall designate when the LEX byte contains aoc data and when it contains data bytes from the bearer data streams. When no bearer data streams are allocated to the interleave data buffer, i.e., all $B_I(ASX) = B_I(LSX) = 0$, then the "synch" byte shall carry the aoc data directly (AEX and LEX bytes, described in 6.2.1.2, do not exist in the interleave buffer in this case). The format of the "synch" byte is described in 6.2.2.2.

Frame 0			crc7	crc6	crc5	crc4	crc3	crc2	crc1	crc0
Frames 1–67	If signals are allocated to interleave buffer	Synch control	sc7	sc6	sc5	sc4	sc3	sc2	sc1	sc0
	If no signals are allocated to interleave buffer	aoc	aoc7	aoc6	aoc5	aoc4	aoc3	aoc2	aoc1	aoc0

Figure 7 – "Synch" byte format – ATU-C transmitter – interleaved data buffer

6.2.1.2 Frame structure

Each frame of data shall be encoded into a multicarrier symbol, as described in 6.3 through 6.6. As is shown in figure 2, each frame is composed of a fast data buffer and an interleaved data buffer, and the frame structure has a different appearance at each of the reference points (A, B, and C). The bytes of the fast buffer shall be clocked into the constellation encoder first, followed by the bytes of the interleaved data buffer. Bytes are clocked least significant bit first.

Each user data stream shall be assigned to either the fast or the interleaved buffer during initialization (see 12.6.1), and a pair of bytes, [B_F, B_I], shall be transmitted for each data stream, where B_F and B_I designate the number of bytes allocated to the fast and interleaved buffers, respectively.

The seven possible [B_F,B_I] pairs to specify the downstream bearer channel rates are

- B_F(ASX), B_I(ASX) for X = 0, 1, 2 and 3, for the downstream simplex channels;
- B_F(LSX), B_I(LSX) for X = 0, 1 and 2, for the (downstream transport of the) duplex channels.

The rules for allocation are:

- for any data stream, X, except the 16 kbit/s C channel option, either B_F(X) = the data rate (in kbit/s) of the fast buffer and B_I (X) = 0, or B_F(X) = 0 and B_I(X) = the data rate (in kbit/s) of the interleaved buffer;

- for the 16 kbit/s C channel option, B_F(LS0) = 255 (binary 11111111) and B_I(LS0) =0, or B_F(LS0) = 0 and B_I(LS0) = 255.

Configurations (i.e., sets of [B_F, B_I]) for the four possible transport classes are given in table 16 for the default configuration (bearers based on 1.536 Mbit/s), and in table 17 for the three possible transport classes for the bearer channel optional rates based on 2.048 Mbit/s.

On-line reconfiguration (e.g., changing the mix of data channel rates or re-allocation of user data streams between fast and interleaved data buffers, or both) is for further study.

Table 16 – Default fast and interleaved data buffer allocations for ATU-C transmitter – Configurations for bearers based on multiples of 1.536 Mbit/s

Signal	B_I (Interleaved data buffer)				B_F (fast data buffer)			
	Transport class 1	Transport class 2	Transport class 3	Transport class 4	Transport class 1	Transport class 2	Transport class 3	Transport class 4
AS0	96	96	48	48	0	0	0	0
AS1	96	48	48	0	0	0	0	0
AS2	0	0	0	0	0	0	0	0
AS3	0	0	0	0	0	0	0	0
LS0	2	2	2	255 (see note)	0	0	0	0
LS1	0	0	0	0	5	0	0	5
LS2	0	0	0	0	12	12	12	0

NOTE – For loop transport class 4, B_F(LS0) = 255 or B_I(LS0) = 255 indicates a 16 kbit/s C channel, which is carried entirely within the synchronization control overhead (LEX byte) as described in 6.2.2; thus, the LS0 sub-channel does not appear as a separate byte within the ADSL frame.

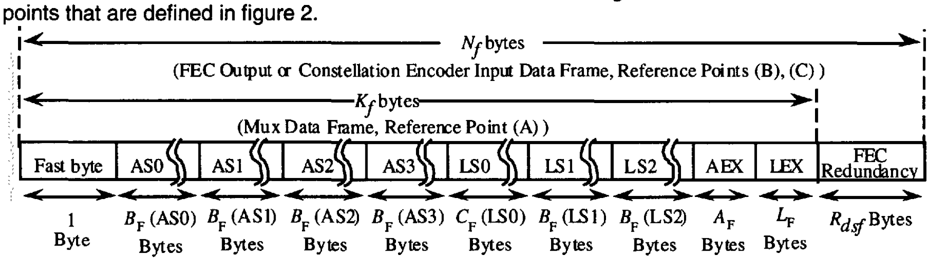
Table 17 – Default fast and interleaved data buffer allocations for ATU-C transmitter – Optional configurations for bearers based on multiples of 2.048 Mbit/s

Signal	B_I (Interleaved data buffer)			B_F (fast data buffer)		
	Transport class 2M-1	Transport class 2M-2	Transport class 2M-3	Transport class 2M-1	Transport class 2M-2	Transport class 2M-3
AS0	64	64	64	0	0	0
AS1	64	64	0	0	0	0
AS2	64	0	0	0	0	0
LS0	2	2	255 (see note)	0	0	0
LS1	0	0	0	5	0	5
LS2	0	0	0	12	12	0

NOTE – For transport class 2M-3, B_F(LS0) = 255 or B_I(LS0) = 255 indicates a 16 kbit/s C channel, which is carried entirely within the synchronization control overhead (LEX byte) as described in 6.2.2; thus, the LS0 sub-channel does not appear as a separate byte within the ADSL frame.

6.2.1.2.1 Fast data buffer

The frame structure of the fast data buffer shall be as shown in figure 8 for the three reference points that are defined in figure 2.



$C_F(\mathrm{LS0}) = 0$ if $B_F(\mathrm{LS0}) = 255$ (Binary 11111111),
$= B_F(\mathrm{LS0})$ otherwise.

$N_f = K_f + R_{dsf}$,
where R_{dsf} = number of FEC Redundancy Bytes.

and $K_f = 1 + \sum_{i=0}^{3} B_F(\mathrm{AS}_i) + A_F + \sum_{j=0}^{2} B_F(\mathrm{LS}_j) + L_F$,

where $A_F = 0$ if $\sum_{i=0}^{3} B_F(\mathrm{AS}_i) = 0$,

1 otherwise,

$L_F = 0$ if $\sum_{i=0}^{3} B_F(\mathrm{AS}_i) = \sum_{j=0}^{2} B_F(\mathrm{LS}_j) = 0$,

1 otherwise

(Note: $L_F = 1$ when $B_F(\mathrm{LS0}) = 255$)

Figure 8 – Fast data buffer – ATU-C transmitter

At reference point A (Mux data frame) in figure 2, the fast buffer shall always contain at least the "fast" byte. This is followed by B_F(AS0) bytes of channel AS0, then B_F(AS1) bytes of channel AS1, B_F(AS2) bytes of channel AS2 and B_F(AS3) bytes of channel AS3. Next come the bytes for any duplex (LSX) channels allocated to the fast buffer. If any B_F(ASX) is non-zero, then both an

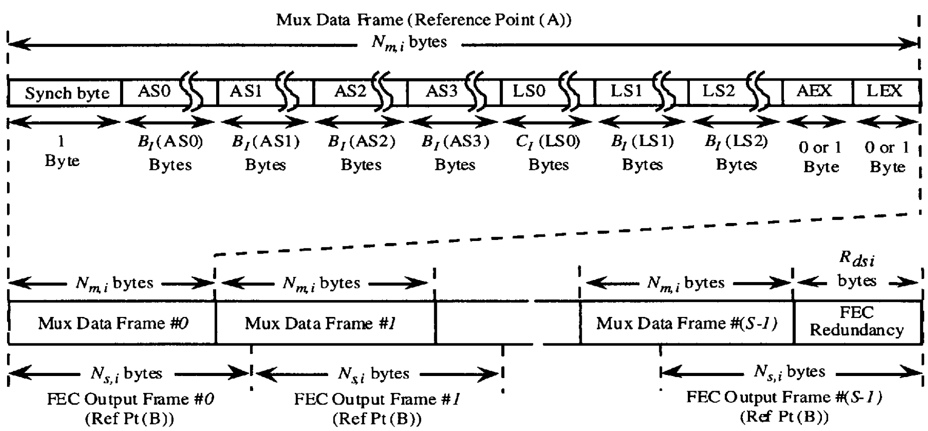
AEX and an LEX byte follow the bytes of the last LSX channel, and if any B_F(LSX)is non-zero, the LEX byte shall be included.

Note that when B_F(LS0) = 255, no bytes are included for the LS0 channel. Instead, the 16 kbit/s C channel shall be transported in every other LEX byte on average, using the synch byte to denote when to add the LEX byte to the LS0 data stream.

R_{dsf} FEC redundancy bytes shall be added to the mux data frame (reference point A) to produce the FEC output data frame (reference point B), where R_{dsf} is given in the RATES1 options used during initialization. For the default configurations given in tables 16 and 17 R_{dsf} = 4; for other configuration options, the value shall be given to the ATU-C in some manner (for example, via a host control port). When no data streams are allocated to the fast buffer R_{dsf} = 0 (no FEC redundancy bytes are added). Because the data from the fast buffer is not interleaved, the constellation encoder input data frame (reference point C) is identical to the FEC output data frame (reference point B).

6.2.1.2.2 Interleaved data buffer

The frame structure of the interleaved data buffer is shown in figure 9 for reference points A and B, which are defined in figure 2 .



$C_I(\text{LS0}) = 0$ if $B_I(\text{LS0}) = 255$ (Binary 11111111),
$= B_I(\text{LS0})$ otherwise.

$$N_{m,i} = 1 + \sum_{i=0}^{3} B_I(\text{AS}_i) + A_I + \sum_{j=0}^{2} B_I(\text{LS}_j) + L_I,$$

where $A_I = 0$ if $\sum^{3} B_I(\text{AS}_i) = 0$,

$= 1$ otherwise,

and $L_I = 0$ if $\sum_{i=0}^{3} B_I(\text{AS}_i) = \sum_{j=0}^{2} B_I(\text{LS}_j) = 0$,

$= 1$ otherwise.

(Note: $L_I = 1$ when $B_I(\text{LS0}) = 255$)

and $N_{s,i} = N_{m,i} + R_{dsi} / S$,
where R_{dsi} = number of FEC Redundancy Bytes,
and S = number of DMT symbols per FEC codeword.

Figure 9 – Interleaved data buffer, ATU-C transmitter

At reference point A, the mux data frame, the interleaved data buffer shall always contain at least the "synch" byte. The rest of the buffer shall be built in the same manner as the fast buffer, substituting B_I in place of B_F. The length of each mux data frame is $N_{m,i}$ bytes, as defined in figure 9.

The FEC coder shall take in S mux data frames and append R_{dsi} FEC redundancy bytes to produce the FEC codeword of length $N_{FEC,i} = S \times N_{m,i} + R_{dsi}$ bytes. The FEC output data frames shall contain $N_{s,i} = N_{FEC,i} / S$ bytes, where $N_{s,i}$ is an integer. When $S > 1$, then for the S frames in an FEC codeword, the FEC output data frame (reference point B) shall partially overlap two mux data frames for all except the last frame, which shall contain the R_{dsi} FEC redundancy bytes.

The FEC output data frames are interleaved to a specified interleave depth. The interleaving process (see 6.4.2) delays each byte of a given FEC output data frame a different amount, so that the constellation encoder input data frames will contain bytes from many different FEC data frames. At reference point A in the transmitter, mux data frame 0 of the interleaved data buffer is aligned with the ADSL superframe and mux data frame 0 of the fast data buffer (this is not true at reference point C). At the receiver, the interleaved data buffer will be delayed by $S \times$ interleave depth $\times$ 250 msec (16 msec for the defaults given in tables 18 and 19) with respect to the fast data buffer, and frame 0 (containing the crc bits for the interleaved data buffer) will appear a fixed number of frames after the beginning of the receiver superframe.

The FEC coding overhead, the number of symbols per FEC codeword, and the interleave depth are listed in tables 18 and 19 for the default configurations (i.e., for all ASX signals plus LS0 allocated to the interleave buffer) in tables 16 and 17. These defaults correspond to the default data rates. For other rates and configurations, the coding parameters shall be given to the ATU-C in some manner (for example, via a host control port).

Table 18 – Default FEC coding parameters and interleave depth for ATU-C transmitter – Default configurations for bearers based on multiples of 1.536 Mbit/s

Transport class	R_{dsi} (FEC redundancy bytes)	S (symbols per codeword)	Interleave depth (FEC codewords)
Transport class 1	16	1	64
Transport class 2	12	1	64
Transport class 3	16	2	32
Transport class 4	16	4	16
Synch byte only	4	4	16

Table 19 – Default FEC coding parameters and interleave depth for ATU-C transmitter – Optional configurations for bearers based on multiples of 2.048 Mbit/s

Transport class	R_{dsi} (FEC redundancy bytes)	S (symbols per codeword)	Interleave depth (FEC codewords)
2M-1	16	1	64
2M-2	12	1	64
2M-3	12	2	32

6.2.1.3 Cyclic redundancy check (crc)

Two cyclic redundancy checks (crcs) – one for the fast data buffer and one for the interleaved data buffer – are generated for each superframe and transmitted in the first frame of the following superframe. Eight bits per buffer type (fast or interleaved) per superframe are allocated to the crc check bits. These bits are computed from the k message bits using the equation:

$$\mathrm{crc}(D) = M(D)\, D^8 \text{ modulo } G(D),$$

where:

$M(D) = m_0 D^{k-1} \oplus m_1 D^{k-2} \oplus .... \oplus m_{k-2} D \oplus m_{k-1}$, is the message polynomial

$G(D) = D^8 \oplus D^4 \oplus D^3 \oplus D^2 \oplus 1$, is the generating polynomial,

$\mathrm{crc}(D) = c_0 D^7 \oplus c_1 D^6 \oplus ..... \oplus c_6 D \oplus c_7$, is the check polynomial,

$\oplus$ indicates modulo-2 addition (exclusive-or)

and D is the delay operator.

That is, crc is the remainder when $M(D)\, D^8$ is divided by G.

The crc check bits are transported in the "fast byte" (8 bits) of frame 0 in the fast data buffer, and the "synch byte"
(8 bits) of frame 0 in the interleaved data buffer.

The bits covered by the crc include
- fast data buffer:
  - *frame 0:* ASX bytes (X = 0, 1, 2, 3), LSX bytes (X = 0, 1, 2), followed by any AEX and LEX bytes.
  - *all other frames:* "fast" byte, followed by ASX bytes (X = 0, 1, 2, 3), LSX bytes (X = 0, 1, 2), and any AEX and LEX bytes.
- interleaved data buffer:
  - *frame 0:* ASX bytes (X = 0, 1, 2, 3), LSX bytes (X = 0, 1, 2), followed by any AEX and LEX bytes.
  - *all other frames:* "synch" byte, followed by ASX bytes (X = 0, 1, 2, 3), LSX bytes (X = 0, 1, 2), and any AEX and LEX bytes.

Each byte shall be clocked into the crc least significant bit first.

The crc field length will vary with the allocation of bytes to the fast and interleaved data buffers (the numbers of bytes in ASX and LSX vary according to the [B_F, B_I] pairs; AEX is present in a given buffer only if at least one ASX is allocated to that buffer; LEX is present in a given buffer only if at least one ASX or one LSX is allocated to that buffer).

Because of the flexibility in assignment of bearer channels to the fast and interleaved data buffers, crc field lengths over an ADSL superframe will vary from approximately 530 bits to approximately 119,000 bits.

6.2.2 Synchronization

The input data streams are synchronized to the ADSL clock using the synchronization control byte and the AEX and LEX bytes. Forward-error-correction coding shall always be applied to the synchronization control byte(s).

6.2.2.1 Synchronization for the fast data buffer

Synchronization control for the fast data buffer can occur in frames 2 through 33 and 36 through 67 of an ADSL superframe as described in 6.2.1.1, where the "fast" byte may be used as the synchronization control byte.

The format of the "fast" byte when used as synchronization control for the fast data buffer is given in table 20.

Table 20 – Fast byte format

Bits	Designation	Codes
sc7, sc6	ASX channel designator	"00" : channel AS0 "01" : channel AS1 "10" : channel AS2 "11" : channel AS3
sc5, sc4	Synchronization control for the designated ASX channel	"00" : do nothing "01" : add AEX byte to designated ASX channel "11" : add AEX and LEX bytes to ASX channel "10" : delete last byte from designated ASX channel
sc3, sc2	LSX channel designator	"00" : channel LS0 "01" : channel LS1 "10" : channel LS2 "11" : no synchronization action; if sc5, sc4 is not equal to "11", LEX may carry LS2 "start of frame" verification pointer (see 6.2.4)
sc1	Synchronization control for the designated LSX channel	"1" : add LEX byte to designated LSX channel "0" : delete last byte from designated LSX channel
sc0	Synch/eoc designator	"0" : perform synchronization control as indicated in sc7-sc1 "1" : this byte of current (even-numbered) frame and of frame that immediately follows is an eoc frame

No synchronization action shall be taken for those frames for which the "fast" byte is used for crc, fixed indicator bits, or eoc.

NOTES

1 ADSL deployments may need to interwork with DS1 (1.544 Mbit/s) or DS1C (3.152 Mbit/s) rates. The synchronization control option that allows adding up to two bytes to an ASX bearer channel provides sufficient overhead capacity to transport combinations of DS1 or DS1C channels transparently (without interpreting or stripping and regenerating the framing embedded within the DS1 or DS1C). The synchronization control algorithm shall, however, guarantee that the fast byte in some minimum number of frames is available to carry eoc frames, so that a minimum eoc rate (4 kbit/s) may be maintained.

2 When the data rate of the C channel is 16 kbit/s, the LS0 sub-channel is transported in the LEX byte, using the "add LEX byte to designated LSX channel", with LS0 as the designated channel, every other frame on average.

6.2.2.2 Synchronization for the interleaved data buffer

Synchronization control for the interleaved data buffer can occur in frames 1 through 67 of an ADSL superframe as described in 6.2.1.1, where the "synch" byte may be used as the synchronization control byte.

The format of the "synch" byte when used as synchronization control for the interleaved data buffer shall be as given in table 21. In the case where no signals are allocated to the interleaved data buffer, the "synch" byte shall carry the aoc data directly, as shown in figure 17 in 6.2.1.1.

Table 21 – Synch byte format – Interleaved data buffer

Bits	Designation	Codes
sc7, sc6	ASX channel designator	"00" : channel AS0 "01" : channel AS1 "10" : channel AS2 "11" : channel AS3
sc5, sc4	Synchronization control for the designated ASX channel	"00" : do nothing "01" : add AEX byte to designated ASX channel "11" : add AEX and LEX bytes to ASX channel "10" : delete last byte from designated ASX channel
sc3, sc2	LSX channel designator	"00" : channel LS0 "01" : channel LS1 "10" : channel LS2 "11" : do nothing to any LSX channel
sc1	Synchronization control for the designated LSX channel	"1" : add LEX byte to designated LSX channel "0" : delete last byte from designated LSX channel
sc0	Synch/aoc designator	"0" : perform synchronization control as indicated in sc7-sc1 "1" : LEX byte carries ADSL overhead control channel data; synchronization control may be allowed for "add AEX" or "delete" as indicated in sc7-sc1

No synchronization action shall be taken during frame 0, where the "synch" byte is used for crc, and the LEX byte carries the aoc.

NOTES

1 ADSL deployments may need to interwork with DS1 (1.544 Mbit/s) or DS1C (3.152 Mbit/s) rates. The synchronization control option that allows adding up to two bytes to an ASX bearer channel provides sufficient overhead capacity to transport combinations of DS1 or DS1C channels transparently (without interpreting or stripping and regenerating the framing embedded within the DS1 or DS1C).

2 When the data rate of the C channel is 16 kbit/s, the LS0 sub-channel is transported in the LEX byte, using the "add LEX byte to designated LSX channel", with LS0 as the designated channel, every other frame on average.

6.2.3 Frame format of ISDN basic access over LS1

When the LS1 channel transports ISDN Basic Access, the framing for this channel shall be a binary equivalent of the frame structure specified for information flow across the ISDN Basic Access Interface point, as specified in ANSI T1.601.

This frame structure within the LS1 channel may be fixed in state SL3 for the downstream direction, and in state SN3 for the upstream direction. During states where the network, or NT1 is not ready, (as generally conveyed by the *act* bit set to 0), the 2B+D fields shall be set to all ones before scrambling. If the ATU is unable to provide SN3 or SL3, then the LS1 channel bytes shall be filled with all ones. State definitions for SN3, SL3, and the *act* bit are specified in ANSI T1.601.

The ISDN Basic Access maintenance definitions and positions, as prescribed by ANSI T1.601, shall retain their definitions across the LS1 channel.

6.2.4 Framing for 384 / 576 kbit/s applications over LS2 (optional)

When the LS2 channel transports 384 or 576 kbit/s applications that require frame integrity, and the LS2 channel is allocated to the non-interleaved data buffer, the ADSL system may, as an option, provide byte and frame integrity of the bearer service channel.

If this option is provided, the ADSL system shall provide byte integrity by mapping the bearer service channel's bytes into ADSL sub-channel LS2 bytes (i.e., mapping bytes across the V- and T-interfaces).

The ADSL system shall provide frame integrity by

- transmitting a non-zero value for the LS2 frame-size parameter during initialization to indicate to the receiver that the LS2 channel should provide frame integrity;
- locally generating framing indication at the receiver, and passing this framing along with the LS2 data stream to the service module at the CI or to the network at the network side of the ADSL link;
- transmitting a frame verification pointer when certain conditions allow across the "U" Interface;
- statistically verifying the bearer service channel framing to the locally-generated framing indication at the receiver.

The LS2 frame-size parameter, FS(LS2), shall be in bytes per (bearer service) frame. For example, for 384 kbit/s service:

- B_F(LS2) = 384 kbit/s / (32 kbit/s/byte/ADSL frame) = 12 bytes per ADSL frame;

- FS(LS2) = 384 kbit/s / (64 kbit/s/byte/bearer service frame) = 6 bytes per bearer service frame.

FS(LS2) shall be set to zero (0) to indicate that framing is not required for the service transported by ADSL sub-channel LS2, or that the transmitter does not provide this option. In either case, no frame verification pointers will be sent by the transmitter.

The ATU-C transmitter may transmit a frame verification pointer when all of the following conditions are satisfied:

a) LS2 is allocated to the fast data buffer;
b) the LS2 frame size is non-zero;
c) no synchronization action is required on any of the ADSL LSX sub-channels in the current frame;
d) the LEX byte is not used for "add 2" synchronization for any of the ADSL ASX sub-channels in the current frame;
e) the transmitter has a valid verification pointer value available for the current frame.

NOTES

1 Condition (c) is satisfied when bits sc3, sc2 (table 21) in the fast byte of frames 2 through 33 or 36 through 67 are "11" and bit sc0 is "0", or the fast byte of the current frame carries crc or indicator bits (i.e., frame numbers 0, 1, 34, and 35).

2 Condition (d) is satisfied when bits sc5, sc4 in the fast byte of frames 2 through 33 or 37 through 67 are "00", "01", or "10" and bit sc0 is "0".

3 The transmitter is not required to transmit a verification pointer in all frames that satisfy conditions (c) and (d).

The frame verification pointer, when transmitted, shall be placed in the LEX byte and shall contain the number of the byte within the current frame's LS2 sub-channel that is the first byte of a bearer service frame, with the first byte of the LS2 sub-channel being byte number zero (0).

When conditions (a) through (d) above are satisfied but the transmitter does not have a verification pointer value to insert, the LEX byte shall be filled with binary 1's to indicate that it does not contain a verification pointer. The receiver shall use the verification pointer only when it falls within a valid range for the configured LS2 rate (i.e., 0 through [B_F(LS2)-1]).

6.3 Scramblers

The binary data streams output from the fast and interleaved buffers shall be scrambled separately using the following algorithm for both:

$$d_n' = d_n \oplus d_{n-18}' \oplus d_{n-23}'$$

where d_n is the n-th output from the fast or interleaved buffer (i.e., input to the scrambler), and d_n' is the n-th output from the corresponding scrambler.

These scramblers shall be applied to the serial data streams without reference to any framing or symbol synchronization. Descrambling in receivers can likewise be performed independent of symbol synchronization.

6.4 Forward error correction

6.4.1 Reed-Solomon coding

R (i.e., R_{dsf} or R_{dsi}) redundant check bytes c_0, c_1, ... , c_{R-2}, c_{R-1} shall be appended to K message bytes m_0, m_1, ... , m_{K-2}, m_{K-1} to form a Reed-Solomon code word of size $N = K + R$ bytes. The check bytes are computed from the message byte using the equation:

$$C(\mathrm{D}) = M(\mathrm{D})\,\mathrm{D}^R \text{ modulo } G(\mathrm{D})$$

where:

$M(\mathrm{D}) = m_0\,\mathrm{D}^{K-1} \oplus m_1\,\mathrm{D}^{K-2} \oplus \ldots \oplus m_{K-1}\,\mathrm{D} \oplus m_K$ is the message polynomial,

$C(\mathrm{D}) = c_0\,\mathrm{D}^{R-1} \oplus c_1\,\mathrm{D}^{R-2} \oplus \ldots \oplus c_{R-2}\,\mathrm{D} \oplus c_{R-1}$ is the check polynomial,

and $G(\mathrm{D}) = \prod (\mathrm{D} \oplus \mathrm{a}^i)$ is the generator polynomial of the Reed-Solomon code, where the index of the product runs from $i = 0$ to R-1. That is, $C(\mathrm{D})$ is the remainder obtained from dividing $M(\mathrm{D})\,\mathrm{D}^R$ by $G(\mathrm{D})$. The arithmetic is performed in the Galois Field GF(256), where a is a primitive element that satisfies the primitive binary polynomial $x^8 \oplus x^4 \oplus x^3 \oplus x^2 \oplus 1$. A data byte ($d_7$, d_6, ... , d_1, d_0) is identified with the Galois Field element $d_7\mathrm{a}^7 \oplus d_6\mathrm{a}^6 \oplus \ldots \oplus d_1\mathrm{a} \oplus d_0$

The number of check bytes R, and the codeword size N vary, as explained in 6.2 .

6.4.2 Interleaving

The Reed-Solomon codewords in the interleave buffer shall be convolutionally interleaved. The interleaving depth varies, as explained in 6.2, but it shall always be a power of 2. Convolutional interleaving is defined by the rule:

> Each of the *N* bytes B_0, B_1, ..., B_{N-1} in a Reed-Solomon codeword is delayed by an amount that varies linearly with the byte index. More precisely, byte B_i (with index i) is delayed by $(D-1) * i$ bytes, where D is the interleave depth.

An example for $N = 5$, $D = 2$ is shown in table 22, where B^j_i denotes the *i*-th byte of the *j*-th codeword.

Table 22 – Convolutional interleaving example for $N = 5$, $D = 2$

Inter-leaver input	B^j_0	B^j_1	B^j_2	B^j_3	B^j_4	B^{j+1}_0	B^{j+1}_1	B^{j+1}_2	B^{j+1}_3	B^{j+1}_4
Inter-leaver output	B^j_0	B^{j-1}_3	B^j_1	B^{j-1}_4	B^j_2	B^{j+1}_0	B^j_3	B^{j+1}_1	B^j_4	B^{j+1}_2

With the above-defined rule, and the chosen interleaving depths (powers of 2), the output bytes from the interleaver always occupy distinct time slots when *N* is odd. When *N* is even, a dummy byte shall be added at the beginning of the codeword at the input to the interleaver. The resultant odd-length codeword is then convolutionally interleaved, and the dummy byte then removed from the output of the interleaver.

6.5 Tone ordering

A DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analog converter. The error signal caused by clipping can be considered as an additive negative impulse for the time sample that was clipped. The clipping error power is almost equally distributed across all tones in the symbol in which clipping occurs. Clipping is therefore most likely to cause errors on those tones that, in anticipation of higher received SNRs, have been assigned the largest number of bits (and therefore have the densest constellations). These occasional errors can be reliably corrected by the FEC coding if the tones with the largest number of bits have been assigned to the interleave buffer.

The numbers of bits and the relative gains to be used for every tone are calculated in the ATU-R receiver, and sent back to the ATU-C according to a defined protocol (see 12.9.8). The pairs of numbers are typically stored, in ascending order of frequency or tone number *i*, in a bit and gain table.

The "tone-ordered" encoding shall assign the first B_F bytes ($8B_F$ bits) from the symbol buffer (see 6.2) to the tones with the smallest number of bits assigned to them, and the remaining B_I bytes ($8B_I$ bits) to the remaining tones.

The ordered bit table b'_i shall be based on the original bit table b_i as follows:

For $k = 0$ to 15
    From the bit table, find the set of all *i* with the number of bits per tone $b_i = k$
    Assign b_i to the ordered bit allocation table in ascending order of *i*

A complementary de-ordering procedure should be performed in the ATU-R receiver. It is not necessary, however, to send the results of the ordering process to the receiver because the bit table was originally generated in the ATU-R, and therefore that table has all the information necessary to perform the de-ordering.

6.6 Constellation encoder – with trellis coding

Block processing of Wei's 16-state 4-dimensional trellis code is optional to improve system performance. An algorithmic constellation encoder shall be used to construct constellations with a maximum number of bits equal to $N_{downmax}$ (≤ 15).

6.6.1 Bit extraction

Data bytes from the DMT symbol buffer shall be extracted according to a re-ordered bit allocation table b'_i, least significant bit first. Because of the 4-dimensional nature of the code, the extraction is based on pairs of consecutive b'_i, rather than on individual ones, as in the non-trellis-coded case. Furthermore, due to the constellation expansion associated with coding, the bit allocation table specifies b'_i, the number of coded bits per tone, which can be any integer from 2 to 15. Given a pair (x,y) of consecutive b'_i, $x+y-1$ bits (reflecting a constellation expansion of 1 bit per 4 dimensions, or one half bit per tone) are extracted from the DMT symbol buffer. These $z = x+y-1$ bits ($t_z, t_{z-1}, \ldots, t_1$) are used to form the binary word u as shown in table 23. The tone ordering procedure ensures $x \leq y$. Single-bit constellations are not allowed because they can be replaced by 2-bit constellations with the same average energy. Refer to 6.6.2 for the reason behind the special form of the word u for the case $x = 0$, $y > 1$.

Table 23 – Forming the binary word *u*

Condition	Binary word / comment
$x > 1$, $y > 1$	$u = (t_z, t_{z-1}, \ldots, t_1)$
$x = 1$, $y \geq 1$	Condition not allowed
$x = 0$, $y > 1$	$u = (t_z, t_{z-1}, \ldots, t_2, 0, t_1, 0)$
$x = 0$, $y \leq 1$	Bit extraction not necessary, no message bits being sent

The last two 4-dimensional symbols in the DMT symbol shall be chosen to force the constellation state to the zero state. For each of these symbols, the 2 LSBs of u are pre-determined, and only $x+y-3$ bits are extracted from the DMT symbol buffer.

6.6.2 Bit conversion

The binary word $u = (u_{z'}, u_{z'-1}, \ldots, u_1)$ determines two binary words $v = (v_{z'-y}, \ldots, v_0)$ and $w = (w_{y-1}, \ldots, w_0)$, which are used to look up two constellation points in the encoder constellation table. For the usual case of x >1 and y >1, $z' = z = x+y-1$, and v and w contain x and y bits respectively. For the special case of $x = 0$ and $y > 0$, $z' = z+2 = y+1$, $v = (v_1, v_0) = 0$ and $w = (w_{y-1}, \ldots, w_0)$. The bits (u_3, u_2, u_1) determine (v_1, v_0) and (w_1, w_0) according to figure 10.

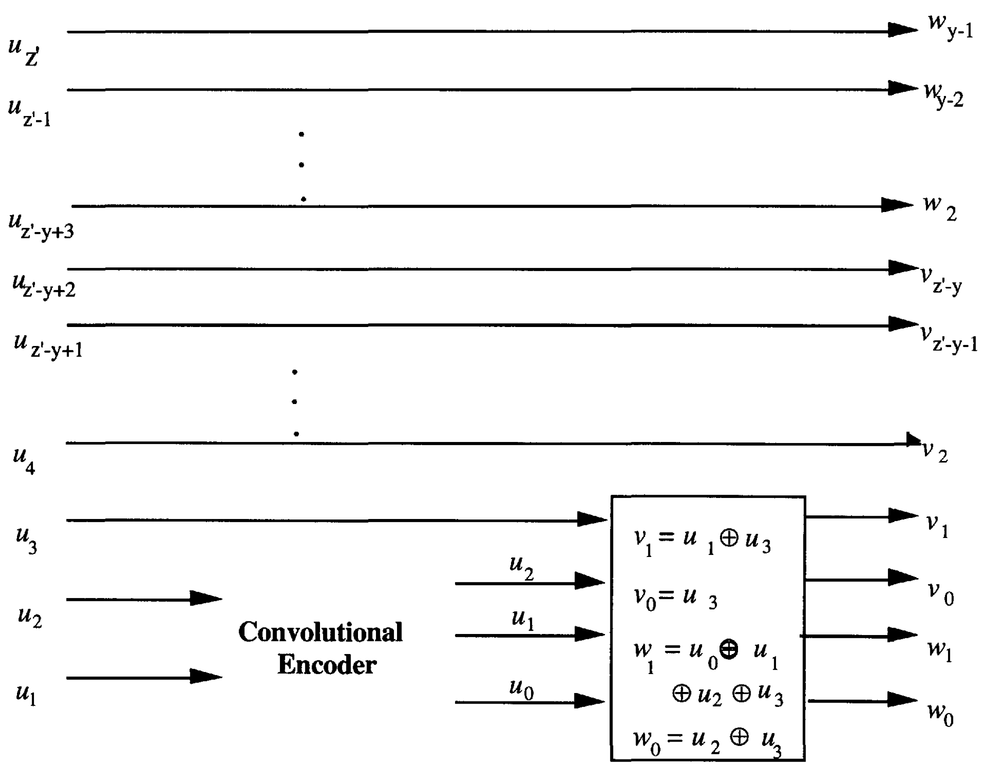


Figure 10 – Conversion of *u* to *v* and *w*

The convolutional encoder shown in figure 10 is a systematic encoder (i.e. u_1 and u_2 are passed through unchanged) as shown in figure 11. The states (S_3, S_2, S_1, S_0) are used to label the states of the trellis shown in figure 12. At the beginning of a DMT symbol period the states are initialized to (0, 0, 0, 0).

The remaining bits of *v* and *w* are obtained from the less significant and more significant parts of ($u_{z'}$, $u_{z'-1}$, .. , u_4), respectively. When $x > 1$ and $y > 1$, $v = (u_{z'-y+2}, u_{z'-y+1}, ..., u_4, v_1, v_0)$ and $w = (u_{z'}, u_{z'-1}, ..., u_{z'-y+3}, w_1, w_0)$. The bit extraction and conversion algorithms have been judiciously designed so that when $x = 0$, $v_1 = v_0 = 0$.

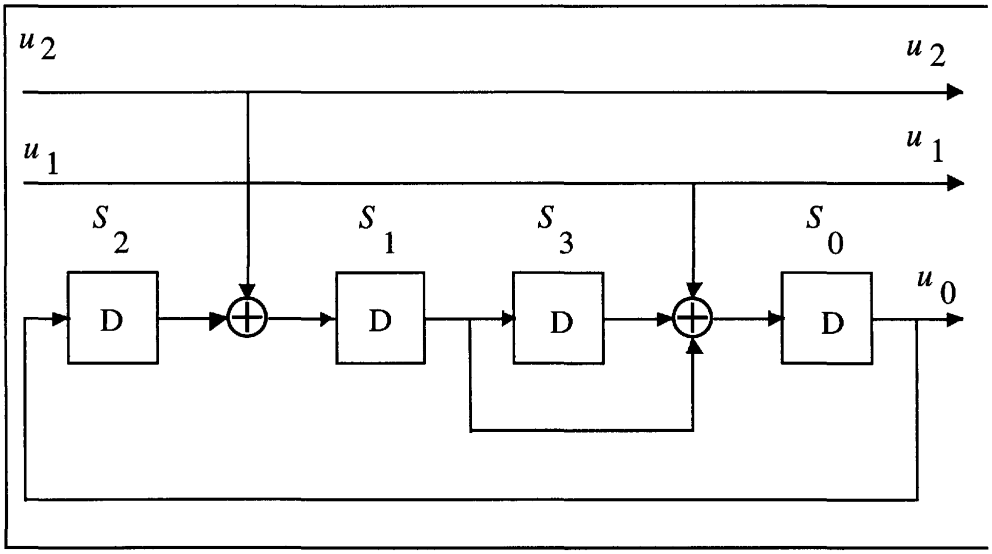


Figure 11 – Finite state machine for Wei's encoder

In order to force the final state to the zero state (0,0,0,0), the 2 LSBs u_1 and u_2 of the final two 4-dimensional symbol in the DMT symbol are constrained to $u_1 = S_1 = S_3$, and $u_2 = S_2$.

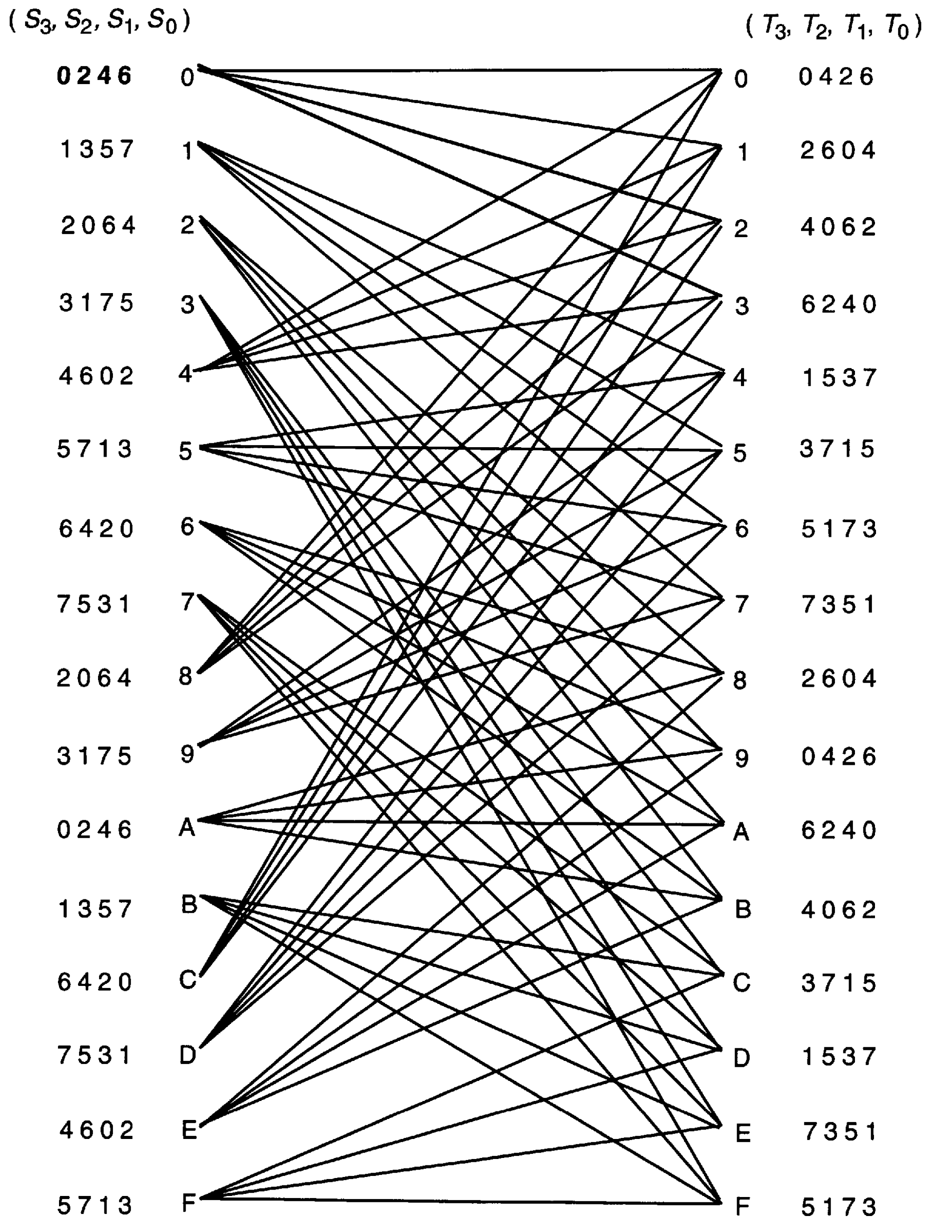


Figure 12 – Trellis diagram

6.6.3 Coset partition and trellis diagram

In a trellis code modulation system, the expanded constellation is labeled and partitioned into subsets ("cosets") using a technique called mapping by set-partitioning. The four-dimensional cosets in Wei's code can each be written as the union of two Cartesian products of two 2-dimensional cosets. For example, $C_4^0 = (C_2^0 \times C_2^1) \cup (C_2^2 \times C_2^3)$. The four constituent 2-dimensional cosets, denoted by C_2^0, C_2^1, C_2^2, C_2^3, are shown in figure 13.

1	3	1	3	1	3	1	3
0	2	0	2	0	2	0	2
1	3	1	3	1	3	1	3
0	2	0	2	0	2	0	2
1	3	1	3	1	3	1	3
0	2	0	2	0	2	0	2
1	3	1	3	1	3	1	3
0	2	0	2	0	2	0	2

Figure 13 – Constituent 2-dimensional cosets for Wei's code

The encoding algorithm ensures that the 2 least significant bits of a constellation point comprise the index i of the 2-dimensional coset C_2^i in which the constellation point lies. The bits (v_1, v_0) and (w_1, w_0) are in fact the binary representations of this index.

The three bits (u_2, u_1, u_0) are used to select one of the 8 possible four-dimensional cosets. The 8 cosets are labeled C_4^i where i is the integer with binary representation (u_2, u_1, u_0). The additional bit u_3 (see figure 10) determines which one of the two Cartesian products of 2-dimensional cosets in the 4-dimensional coset is chosen. The relationship is shown in table 24 . The bits (v_1, v_0) and (w_1, w_0) are computed from (u_3, u_2, u_1, u_0) using the linear equations given in figure 10.

Table 24 – Relation between 4-dimensional and 2-dimensional cosets

4-D Coset	$u_3\ u_2\ u_1\ u_0$	$v_1\ v_0$	$w_1\ w_0$	2-D Cosets
C_4^0	0 0 0 0 1 0 0 0	0 0 1 1	0 0 1 1	$C_2^0 \times C_2^0$ $C_2^3 \times C_2^3$
C_4^4	0 1 0 0 1 1 0 0	0 0 1 1	1 1 0 0	$C_2^0 \times C_2^3$ $C_2^3 \times C_2^0$
C_4^2	0 0 1 0 1 0 1 0	1 0 0 1	1 0 0 1	$C_2^2 \times C_2^2$ $C_2^1 \times C_2^1$
C_4^6	0 1 1 0 1 1 1 0	1 0 0 1	0 1 1 0	$C_2^2 \times C_2^1$ $C_2^1 \times C_2^2$
C_4^1	0 0 0 1 1 0 0 1	0 0 1 1	1 0 0 1	$C_2^0 \times C_2^2$ $C_2^3 \times C_2^1$
C_4^5	0 1 0 1 1 1 0 1	0 0 1 1	0 1 1 0	$C_2^0 \times C_2^1$ $C_2^3 \times C_2^2$
C_4^3	0 0 1 1 1 0 1 1	1 0 0 1	0 0 1 1	$C_2^2 \times C_2^0$ $C_2^1 \times C_2^3$
C_4^7	0 1 1 1 1 1 1 1	1 0 0 1	1 1 0 0	$C_2^2 \times C_2^3$ $C_2^1 \times C_2^0$

Figure 12 shows the trellis diagram based on the finite state machine in figure 11, and the one-to-one correspondence between (u_2,u_1,u_0) and the 4-dimensional cosets. In the figures, $S = (S_3,S_2,S_1,S_0)$ represents the current state, while $T = (T_3,T_2,T_1,T_0)$ represents the next state in the finite state machine. S is connected to T in the constellation diagram by a branch determined by the values of u_2 and u_1. The branch is labeled with the 4-dimensional coset specified by the values of u_2, u_1 (and $u_0 = S_0$, see figure 11). To make the constellation diagram more readable, the indices of the 4-dimensional coset labels are listed next to the starting and end points of the branches, rather than on the branches themselves. The leftmost label corresponds to the uppermost branch for each state. The constellation diagram is used when decoding the trellis code by the Viterbi algorithm.

6.6.4 Constellation encoder

For a given sub-channel, the encoder shall select an odd-integer point (X,Y) from the square-grid constellation based on the b bits $\{v_{b-1},v_{b-2}, ..., v_1,v_0\}$. For convenience of description, these b bits are identified with an integer label whose binary representation is $(v_{b-1},v_{b-2}, ..., v_1,v_0)$. For example, for b=2, the four constellation points are labeled 0,1,2,3 corresponding to (v_1,v_0) = (0,0), (0,1), (1,0), (1,1), respectively.

6.6.4.1 Even values of b

For even values of b, the integer values X and Y of the constellation point (X,Y) shall be determined from the b bits $\{v_{b-1}, v_{b-2}, ..., v_1, v_0\}$ as follows. X and Y are the odd integers with twos-complement binary representations $(v_{b-1}, v_{b-3}, ..., v_1, 1)$ and $(v_{b-2}, v_{b-4}, ..., v_0, 1)$, respectively. The most significant bits (MSBs), v_{b-1} and v_{b-2}, are the sign bits for X and Y, respectively. Figure 14 shows example constellations for b = 2 and b= 4.

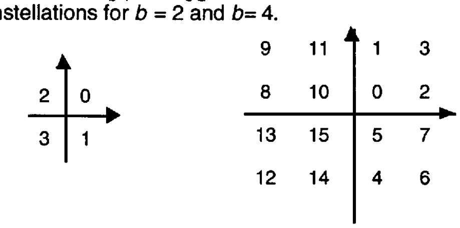


Figure 14 – Constellation labels for b = 2 and b = 4

The 4-bit constellation can be obtained from the 2-bit constellation by replacing each label n by the 2 × 2 block of labels:

$4n+1$	$4n+3$
$4n$	$4n+2$

The same procedure can be used to construct the larger even-bit constellations recursively.

The constellations obtained for even values of b are square in shape. The least significant bits $\{v_1,v_0\}$ represent the coset labeling of the constituent 2-dimensional cosets used in the 4-dimensional Wei trellis code.

6.6.4.2 Odd values of b, $b = 3$

Figure 15 shows the constellation for the case b = 3.

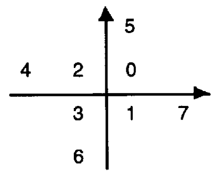


Figure 15 – Constellation labels for $b = 3$

6.6.4.3 Odd values of b, $b>3$

If b is odd and greater than 3, the 2 MSBs of X and the 2 MSBs of Y are determined by the 5 MSBs of the b bits. Let $c = (b+1)/2$, then X and Y have the twos-complement binary representations $(X_c, X_{c-1}, v_{b-4}, v_{b-6}, ..., v_3, v_1, 1)$ and $(Y_c, Y_{c-1}, v_{b-5}, v_{b-7}, v_{b-9}, ..., v_2, v_0, 1)$, where X_c and Y_c are the sign bits of X and Y respectively. The relationship between X_c, X_{c-1}, Y_c, Y_{c-1} and v_{b-1}, v_{b-2}, ..., v_{b-5} is shown in the table 25.

Table 25 – Determining the top 2 bits of X and Y

$v_{b-1}, v_{b-2}, ..., v_{b-5}$	X_c, X_{c-1}	Y_c, Y_{c-1}
00000	00	00
00001	00	00
00010	00	00
00011	00	00
00100	00	11
00101	00	11
00110	00	11
00111	00	11
01000	11	00
01001	11	00
01010	11	00
01011	11	00
01100	11	11
01101	11	11
01110	11	11
01111	11	11
10000	01	00
10001	01	00
10010	10	00
10011	10	00
10100	00	01
10101	00	10
10110	00	01
10111	00	10
11000	11	01
11001	11	10
11010	11	01
11011	11	10
11100	01	11
11101	01	11
11110	10	11
11111	10	11

Figure 16 shows the constellation for the case b = 5.

	24	26	20	22	
19	09	11	01	03	17
18	08	10	00	02	16
31	13	15	05	07	29
30	12	14	04	06	28
	25	27	21	23	

Figure 16 – Constellation labels for $b = 5$

The 7-bit constellation shall be be obtained from the 5-bit constellation by replacing each label n by the 2×2 block of labels:

$$\begin{matrix} 4n+1 & 4n+3 \\ 4n & 4n+2 \end{matrix}$$

The same procedure shall then be used to construct the larger odd-bit constellations recursively. Note also that the least significant bits $\{v_1, v_0\}$ represent the coset labeling of the constituent 2-dimensional cosets used in the 4-dimensional Wei trellis code.

6.7 Constellation encoder – without trellis coding

An algorithmic constellation encoder shall be used to construct constellations with a maximum number of bits equal to $N_{downmax}$ (≤ 15). The constellation encoder shall not use trellis coding with this option.

6.7.1 Bit extraction

Data bytes from the DMT symbol buffer shall be extracted according to a re-ordered bit allocation table b'_i, least significant bit first. The number of bits per tone, b'_i, can take any non-negative integer values not exceeding $N_{downmax}$, with the exception of $b'_i = 1$. For a given tone $b'_i = b$ bits are extracted from the DMT symbol buffer, and these bits form a binary word $\{v_{b-1}, v_{b-2}, ..., v_1, v_0\}$.

6.7.2 Constellation encoder

The constellation encoder shall be as specified in 6.6.4.

6.8 Gain scaling

A gain adjuster, g_i is used to effect a frequency-variable transmit power spectral density (PSD). It may have two factors:

- a gross gain adjustment of either 1.414 or 2.0 (i.e., 3 or 6 dB), which may be required for sub-carriers # 51 and above (see 12.9.8);
- a fine gain adjustment with a range of approximately 0.8 to 1.2 (i.e., 0 +1.5 dB), which may be used to equalize the expected error rates for all the sub-channels.

Each point, (X_i, Y_i), or complex number, $Z_i = X_i + jY_i$, output from the encoder is multiplied by g_i: $Z_i' = g_i Z_i$

NOTE – The g_i define a scaling of the root mean square (rms) sub-carrier levels relative to those used in C-MEDLEY (see 12.6.6). They are independent of any methods that manufacturers may use to simplify implementation (e.g., constellation nesting).

6.9 Modulation

6.9.1 Sub-carriers

The frequency spacing, Δf, between sub-carriers shall be 4.3125 kHz, with a tolerance of + 50 ppm.

6.9.1.1 Data sub-carriers

The channel analysis signal defined in 12.6.6 allows for a maximum of 255 carriers (at frequencies $n\Delta f$, $n = 1$ to 255) to be used. If echo cancelling (EC) is used to separate downstream and upstream signals, then the lower limit on n is determined by the ADSL/POTS splitting filters; if frequency division multiplexing (FDM) is used the lower limit is set by the down – up splitting filters. The cut-off frequencies of these filters are completely at the discretion of the manufacturer because, in either case, the range of usable n is determined during the channel estimation.

6.9.1.2 Pilot

Carrier #64 ($f = 276$ kHz) shall be reserved for a pilot; that is $b_{64} = 0$ and $g_{64} = 1$. The data modulated onto the pilot sub-carrier shall be a constant {0,0}. Use of this pilot allows resolution of sample timing in a receiver modulo-8 samples. Therefore a gross timing error that is an integer multiple of 8 samples could still persist after a micro-interruption (e.g., a temporary short-circuit, open circuit or severe line hit); correction of such timing errors is made possible by the use of the synchronization symbol defined in 6.9.3.

6.9.1.3 Nyquist frequency

The carrier at the Nyquist frequency (#256) shall not be used for data; other possible uses are for further study.

6.9.2 Modulation by the inverse discrete Fourier transform (IDFT)

The modulating transform defines the relationship between the 512 real values x_k and the Z_i'

$$x_k = \sum_{i=0}^{511} \exp\left(\frac{j\pi ki}{256}\right) Z_i' \quad \text{for } k = 0 \text{ to } 511$$

The encoder and scaler generate only 255 complex values of Z_i' (plus zero at dc, and one real value if the Nyquist frequency is used). In order to generate real values of x_k these values shall be augmented so that the vector Z' has Hermitian symmetry. That is,

$$Z_i' = \text{conj}\,(Z_{512-i}') \quad \text{for } i = 257 \text{ to } 511$$

6.9.3 Synchronization symbol

The synchronization symbol permits recovery of the frame boundary after micro-interruptions that might otherwise force retraining.

The symbol rate, $f_{symb} = 4$ kHz, the carrier separation, $\Delta f = 4.3125$ kHz, and the IDFT size, $N = 512$, are such that a cyclic prefix of 40 samples could be used. That is,

$$(512 + 40) \times 4.0 = 512 \times 4.3125 = 2208$$

The cyclic prefix shall, however, be shortened to 32 samples, and a synchronization symbol (with a nominal length of 544 samples) inserted after every 68 data symbols. That is,

$(512 + 32) \times 69 = (512 + 40) \times 68$

The data pattern used in the synchronization symbol shall be the pseudo-random sequence PRD, (d_n, for n = 1 to 512) defined by

$d_n = 1$ for n = 1 to 9
$d_n = d_{n4} \approx d_{n9}$ for n =10 to 512

The first pair of bits (d_1 and d_2) shall be used for the dc and Nyquist sub-carriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); the first and second bits of subsequent pairs are then used to define the X_i and Y_i. for i = 1 to 255 as follows:

d_{2i+1}, d_{2i+2}	X_i, Y_i.
0 0	+ +
0 1	+ −
1 0	− +
1 1	− −

NOTES

1 The period of the PRD is only 511 bits, so $d_{512} = d_1$.
2 The $d_1 - d_9$ are re-initialized for each symbol, so each symbol of C-REVERB1 uses the same data.

Bits 129 and 130, which modulate the pilot carrier (i = 64), shall be overwritten by {0,0}: generating the {+,+} constellation.

The minimum set of sub-carriers to be used is the set used for data transmission (i.e., those for which $b_i > 0$); sub-carriers for which $b_i = 0$ may be used at a reduced PSD as defined in 6.13.4. The data modulated onto each sub-carrier shall be as defined above; it shall not depend on which sub-carriers are used.

6.10 Cyclic prefix

The last 32 samples of the output of the IDFT (x_k for k = 480 to 511) shall be prepended to the block of 512 samples and read out to the digital-to-analog converter (DAC) in sequence. That is, the subscripts, k, of the DAC samples in sequence are 480.....511,0........511.

The cyclic prefix shall be used for data and synchronization symbols beginning with the R-RATES1 segment of the initialization sequence, as defined in 12.7.4.

6.11 Transmitter dynamic range

The transmitter includes all analog transmitter functions: the D/A converter, the anti-aliasing filter, the hybrid circuitry, and the POTS splitter. The transmitted signal shall conform to the frequency requirements as described in 6.9.1 for frequency spacing.

6.11.1 Maximum clipping rate

The maximum output signal of the transmitter shall be such that the probability of the signal being clipped is no greater than 10^{-7}.

6.11.2 Noise/Distortion floor

The Signal to Noise plus Distortion (SINAD) ratio of the transmitted signal in a given sub-carrier is defined as the ratio of the rms value of the full-amplitude tone in that sub-carrier to the rms sum of all the non-tone signals in the 4.3125 kHz frequency band centered on the sub-carrier frequency. The SINAD is characterized for each sub-carrier used for transmission: $SINAD_i$ represents the signal to noise plus distortion available on the transmitted signal in the ith sub-carrier.

Over the transmission frequency band, the SINAD of the transmitter in any sub-carrier shall be no less than $(3N_{downi} + 20)$ dB, where N_{downi} is defined as the size of the constellation (in bits) to be used on sub-carrier i. The minimum transmitter SINAD shall be at least 38dB (corresponding to an N_{downi} of 6) for any sub-carrier.

6.12 Transmitter spectral response

Figure 17 shows a representative spectral response mask for the transmitted signal. The pass band is defined as the frequency range over which the modem transmits. The low frequency stop band is defined as the POTS band; the high frequency stop band is defined as frequencies greater than 2.208 Mhz.

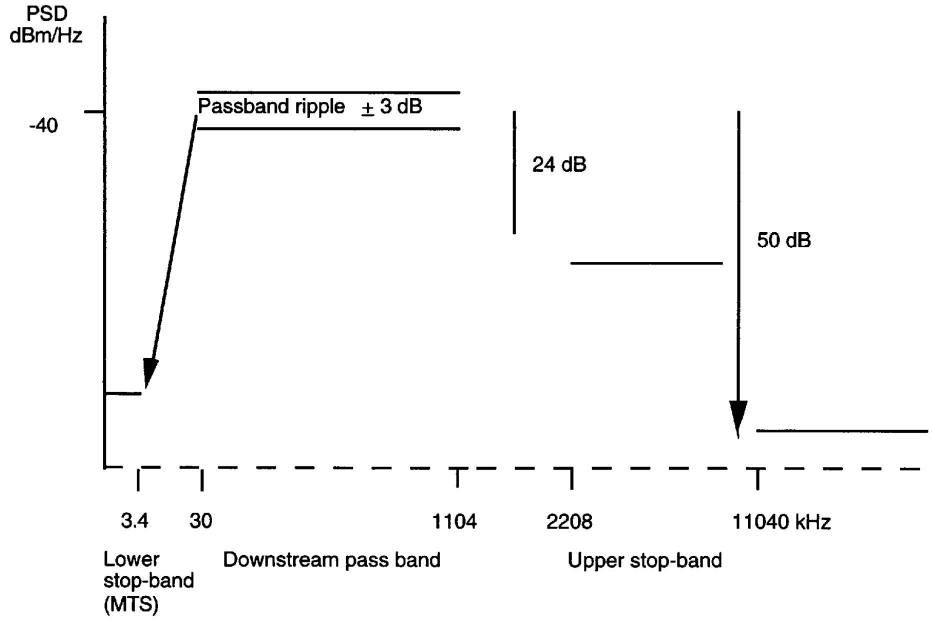


Figure 17 – ATU-C transmitter PSD mask

6.12.1 Pass band response

The pass band ripple shall be no greater than 3 dB, and the group delay variation over the pass band shall not exceed 50 µsec.

6.12.2 Low frequency stop band rejection

The spectral characteristics of the output in the POTS band shall conform to the specifications in 10.7.

6.12.3 High frequency stop band rejection

The PSD in the band above 2.208 MHz shall be at least 24 dB below the spectral density of the pass-band mask. (see 12.4.3) . The PSD in the band above 11.04 MHz shall be at least 50 dB below the spectral density of the pass-band mask.

6.13 Transmit power spectral density and aggregate power level

There are three different PSD masks for the ATU-C transmit signal, depending on the type of signal sent. In all cases the power in the voice-band that is delivered to the Public Switched Telephone Network (PSTN) interface shall conform to the specification given in 10.7

6.13.1 All initialization signals (except C-ECT) starting with C-REVERB1

The PSD in the band from 25 to 1100 kHz, shall not exceed –40 dBm/Hz for a total power of not greater than 20 dBm. The power in the voice band delivered to the PSTN interface shall conform to the requirements of 10.7. If measurement of the upstream power indicates that power cut-back is necessary, then the PSD should be set at –42, –44, –46, –48, –50, or –52 dBm/Hz (see 12.4.3).

6.13.2 C-ECT

Because C-ECT is a vendor defined signal (see 12.4.5), the PSD specification shall be interpreted only as a maximum. This maximum level is –40 dBm/Hz for the band from 18 to 1100 kHz. Sub-carriers 1 – 5 may be used, but the power in the voice-band that is delivered to the PSTN interface shall conform to the specification given in 10.7.

6.13.3 Steady-state data signal

The PSD in the band from 25 to 1100 kHz shall normally (i.e., without power cut-back or power boost) be –40 dBm/Hz with a maximum of –37 dBm/Hz; levels lower than –40 dBm/Hz on some carriers are discretionary. The normal aggregate power level shall not exceed (–4 +10 log(*ncdown*)) dBm, where *ncdown* is the number of sub-carriers used (20.4 dBm if all sub-carriers are used). The PSD and aggregate power may, however, be changed in any of the following circumstances:

a) Power cut-back: in this case the PSD and the aggregate power level will be reduced by n multiples of 2 dB (n = 0 to 5) so that they are as follows
- PSDmax = $-37 - 2n$ dBm/Hz
- Total power = $-4 - 2n + 10\log(ncdown)$ dBm

b) the bits and gains table (see R-B&G in 12.9.8) from ATU-R during initialization may eliminate some of the sub-carriers, and finely adjust (i.e., within ± 3 dB range) the level of others in order to equalize expected error rates on each of the sub-channels;

c) a power boost: the PSD and aggregate power shall not exceed the following
- PSDmax = –37 dBm/Hz for $0 < i \leq 50$; that is, frequency below 220 kHz
  –31 dBm/Hz for $51 \leq i < 256$; that is frequency above 220 kHz.
- Total power = the sum of the powers (–4 + 10 log(*ncdown1*)) and (2 + 10log(*ncdown2*)),

where *ncdown1* and *ncdown2* are the number of sub-carriers used in the sub-bands $i = 0$ to 50, and $i = 51$ to 255, respectively

These specifications are shown in figure 18, where the possible power cut-back in multiples of 2 dBm and power boost of 6 dBm above 220 kHz are illustrated .

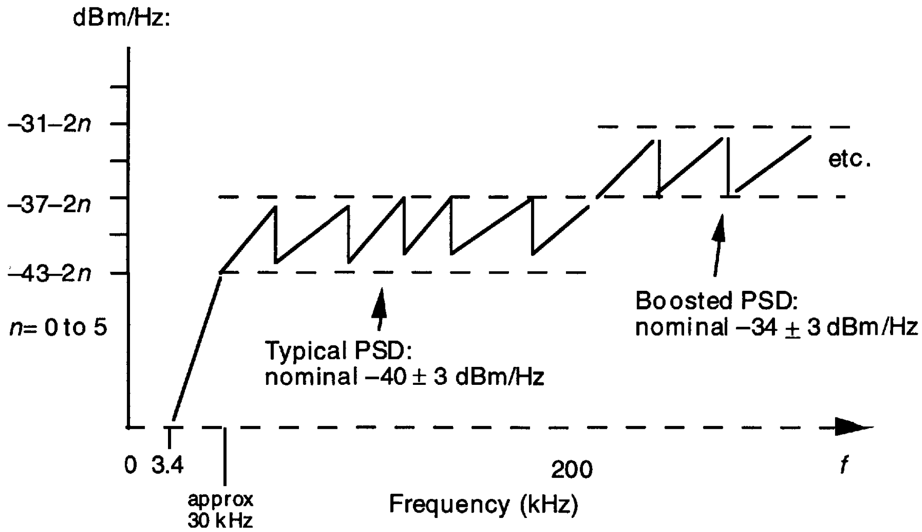


Figure 18 – ATU-C transmitter PSD mask: pass-band detail

6.13.4 Synchronization symbol

The PSD of those sub-carriers for which $b_i > 0$ or $b_i = 0$ and $g_i > 0$ shall be the same as for the initialization signal C-REVERB1; that is, nominally –40 dBm/Hz. The PSD for those sub-carriers for which $b_i = 0$ and $g_i = 0$ shall be no higher than –48 dBm/Hz.

The PSD of a synchroniazation symbol thus differs from that of the data signals surrounding it by the g_i, which are applied only to the data carriers. These g_i were calculated for the multipoint constellations in order to equalize the expected error rate on all sub-channels, and are therefore irrelevant for most of the 4QAM signals of the synchronization symbol.

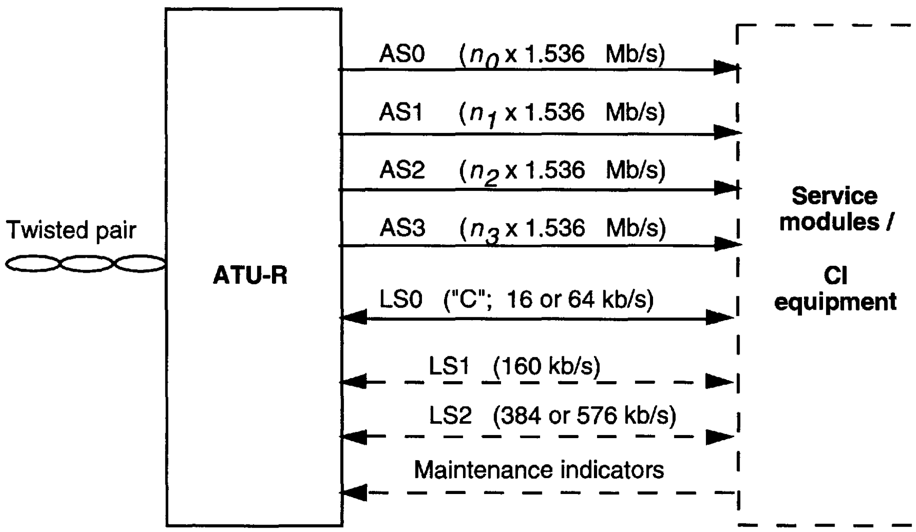
7 ATU-R functional characteristics

7.1 ATU-R input and output data interfaces

The functional data interfaces at the ATU-R are shown in figure 19 . Output interfaces for the high-speed downstream simplex bearer channels are designated AS0 through AS3; input – output interfaces for the duplex bearer channels are designated LS0 through LS2. There may also be a functional interface to transport maintenance indicators from the SMs (service modules) to the ATU-R; this interface may physically be combined with the LS0 upstream interface.

The data rates of the input and output data interfaces at the ATU-R for the default configurations are specified in this clause.

The total net bearer capacity that can be transmitted in the upstream direction depends on the loop characteristics. The rate of the duplex bearer at the LS0 interface and the availability of the LS1 and LS2 options correspond to the transport class as discussed in 5.3, for the default configurations.



NOTE – ◄— — — — ► indicates optional duplex channels (LS1 and LS2).

Figure 19 – ATU-R data interfaces

7.1.1 Downstream simplex channels – Transceiver bit rates

The simplex channels are transported in the downstream direction only; therefore their data interfaces at the ATU-R operate only as outputs. The rates are the same as those for the ATU-C transmitter, as specified in 6.1.1.

7.1.2 Duplex channels – Transceiver bit rates

The duplex channels are transported in both directions, so the ATU-R shall provide both input and output data interfaces. The rates are the same as for the ATU-C, as specified in 6.1.2.

7.2 Framing

Framing of the upstream signal (ATU-R transmitter) is specified in this subclause; it closely follows the downstream framing (ATU-C transmitter), which is specified in 6.2, but with the following exceptions:

- there are no ASX channels or an AEX byte;
- a maximum of three channels exist, so that only three B_F, B_I pairs are specified;
- the default FEC coding parameters and interleave depth differ (see table 26);
- four bits of the "fast" and "synch" bytes are unused (corresponding to the bit positions used by the ATU-C transmitter to specify synchronization control for the ASX channels) (see tables 27 and 28);
- if the LS2 frame integrity option is installed, condition (d) in 6.2.4 does not apply for the insertion of an LS2 frame verification pointer.

7.2.1 Data symbols

The ATU-R transmitter is functionally similar to the ATU-C transmitter, as specified in 6.2.1, with the exception that up to three duplex data channels are synchronized to the 4 kHz ADSL DMT symbol rate (instead of up to four simplex and three duplex channels as is the case for the ATU-C) and multiplexed into the two separate buffers (fast and interleaved). The ATU-R transmitter and its associated reference points for data framing are identical to the structure shown in figure 2, with the exception that the AS0..AS3 channels do not appear at the input of the Mux/Synch Control.

7.2.1.1 Superframe structure

The superframe structure of the ATU-R transmitter shall be identical to that of the ATU-C transmitter, as specified in 6.2.1.1.

7.2.1.2 Frame structure

Each frame of data shall be encoded into a multicarrier symbol, as described in 7.3 through 7.6. As specified for the ATU-C and shown in figure 2, each frame is composed of a fast data buffer and an interleaved data buffer, and the frame structure has a different appearance at each of the reference points (A, B, and C). The bytes of the fast buffer shall be clocked into the constellation encoder first, followed by the bytes of the interleaved data buffer. Bytes are clocked least significant bit first.

The assignment of user data streams to the fast and interleaved buffers shall be configured during initialization (see 12.6) with the exchange of a (B_F,B_I) pair for each data stream, where B_F designates the number of bytes of a given data stream to allocate to the fast buffer, and B_I designates the number of bytes allocated to the interleaved data buffer.

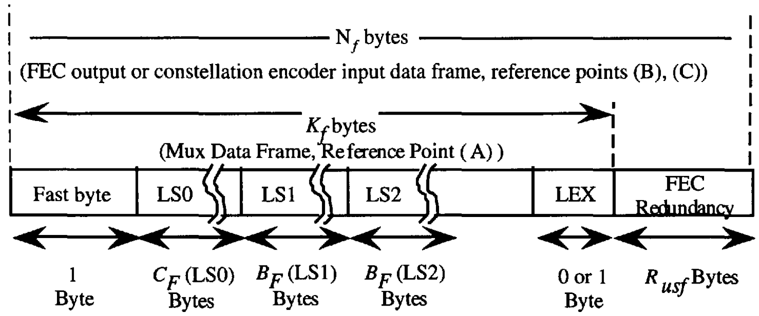
The three possible (B_F,B_I) pairs are B_F(LSX), B_I(LSX) for X = 0, 1 and 2, for the duplex channels; they are specified as for the ATU-C in 6.2.1.2.

The three values of the (B_F,B_I) pairs for the default configurations shall be as specified for the ATU-C in table 16.

7.2.1.2.1 Fast data buffer

The frame structure of the fast data buffer is shown in figure 20 for the three reference points that are defined in figure 2 . This structure is the same as that specified for the ATU-C with the following exceptions:

- ASX bytes do not appear;
- the AEX byte does not appear;
- R_{usf} FEC redundancy bytes are used (as contrasted with R_{dsf}).



$$K_f = 1 + \sum_{j=0}^{2} B_F(LS_j) + L_F,$$

$$\text{where } L_F = \begin{cases} 0, & \sum_{j=0}^{2} B_F(LS_j) = 0, \\ 1 & \text{otherwise} \end{cases}$$

$$C_F(LS0) = \begin{cases} 0, & B_F(LS0) = 255, \\ B_F(LS0) & \text{otherwise.} \end{cases}$$

$$N_f = K_f + R_{usf},$$

where R_{usf} = # FEC Redundancy Bytes

NOTE – L_F = 1 when B_F(LS0) = 255.

Figure 20 – Fast data buffer – ATU-R transmitter

At reference point A in figure 2, the mux data frame, the fast buffer always contains at least the "fast" byte. This is followed by B_F(LS0) bytes of channel LS0, then B_F(LS1) bytes of channel LS1, and B_F(LS2) bytes of channel LS2, and if any B_F(LSX) is non-zero, an LEX byte.

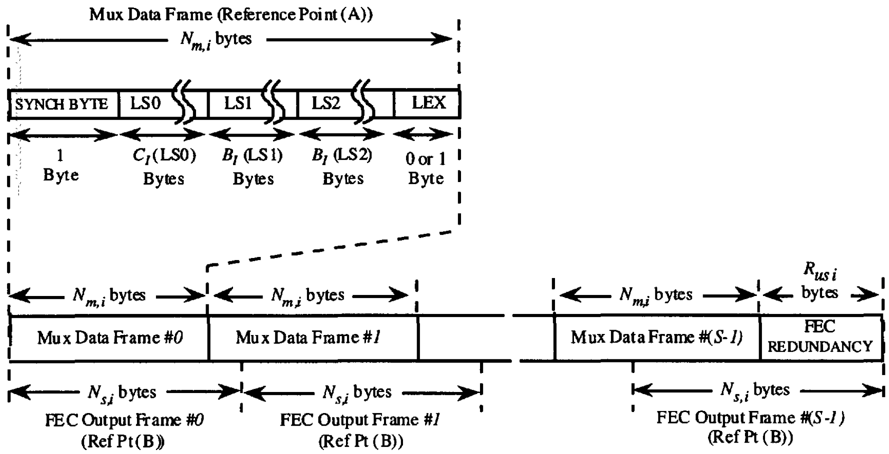
When B_F(LS0) = 255 (Binary 11111111), no separate bytes are included for the LS0 channel. Instead, the 16 kbit/s C channel is transported in every other LEX byte on average, using the synch byte to denote when to add the LEX byte to the LS0 data stream.

R_{usf} FEC redundancy bytes are added to the mux data frame (reference point A) to produce the FEC output data frame (reference point B), where R_{usf} is given in the C-RATES1 signal options received from the ATU-C during initialization (see clause 12). R_{usf} is equal to 4 for the default configurations specified in 6.2.1.2. When no data streams are allocated to the fast buffer, R_{usf} = 0 (no FEC redundancy bytes are added). Because the data from the fast buffer is not interleaved, the constellation encoder input data frame (reference point C) is identical to the FEC output data frame (reference point B).

7.2.1.2.2 Interleaved data buffer

The frame structure of the interleaved data buffer is shown in figure 21 for the three reference points that are defined in figure 2. This structure is the same as that specified for the ATU-C, with the following exceptions:

- ASX bytes do not appear;
- the AEX byte does not appear;
- R_{usi} FEC redundancy bytes are used (contrasted with R_{dsi}).



$N_{m,i} = 1 + \sum_{j=0}^{2} B_I(LS_j) + L_I$,

where $L_I = \begin{cases} 0, \sum_{j=0} B_I(LS_j) = 0, \\ 1 \text{ otherwise.} \end{cases}$

(Note: $L_I = 1$ when $B_I(LS0) = 255$)

$C_I(LS0) =$ 0, $B_I(LS0) = 255$ (Binary 1111111),
$B_I(LS0)$ otherwise.

$N_{s,i} = (S * N_{m,i} + R_{usi}) / S$,

where R_{usi} = # FEC Redundancy Bytes,
and S = # DMT symbols per FEC codeword.

Figure 21 – Interleaved data buffer – ATU-R transmitter

The FEC coding overhead, the number of symbols per FEC codeword, and the interleave depth are given in the C-RATES1 options received from the ATU-C during initialization (see clause 12). For the default configurations specified in 6.2.1.2, the coding parameters are given in table 26 .

Table 26 – Default FEC coding parameters and interleave depth – ATU-R transmitter

	R_{usi} (FEC redundancy bytes)	S (symbols per codeword)	Interleave depth (FEC codewords)
Transport classes 1, 2M-1	16	8	8
Transport classes 2, 3, 2M-2	16	16	4
Transport classes 4, 2M-3	16	16	4
Synch byte only	4	4	16

7.2.1.3 Cyclic redundancy check (crc)

Two cyclic redundancy checks (crcs) – one for the fast data buffer and one for the interleaved data buffer – are generated for each superframe and transmitted in the first frame of the following superframe. Eight bits per buffer type (fast or interleaved) per superframe are allocated to the crc check bits.

The crc bits are transported in the "fast byte" (8 bits) of frame 0 in the fast data buffer, and the "synch byte" (8 bits) of frame 0 in the interleaved data buffer.

The bits covered by the crc include;
- for the fast data buffer:
  - *frame 0:* LSX bytes (X = 0, 1, 2), followed by the LEX byte;
  - *all other frames:* "fast" byte, followed by LSX bytes (X = 0, 1, 2), and LEX byte.

- for the interleaved data buffer:
  - *frame 0:* LSX bytes (X = 0, 1, 2), followed by the LEX byte;
  - *all other frames:* "synch" byte, followed by LSX bytes (X = 0, 1, 2), and LEX byte.

Each byte shall be clocked into the crc least significant bit first.

The crc-generating polynomial, and the method of generating the crc byte are the same as for the downstream data; these are specified in 6.2.1.3.

7.2.2 Synchronization

The input data streams shall be synchronized to the ADSL clock using the synchronization control byte and the LEX byte. Forward-error-correction coding is always applied to the synchronization control byte(s).

7.2.2.1 Synchronization for the fast data buffer

Synchronization control for the fast data buffer can occur in frames 2 through 33 and 36 through 67 of an ADSL superframe as described in 7.2.1.1, where the "fast" byte may be used as the synchronization control byte.

The format of the "fast" byte when used as synchronization control for the fast data buffer shall be as given in table 27.

In the case where no signals are allocated to the interleaved data buffer, the "synch" byte shall carry the aoc data directly as shown in figure 7.

Table 27 – Fast byte format for synchronization – Fast data buffer

Bit	Application	Specific usage
sc7-sc4	not used	set to "0" until specified otherwise
sc3, sc2	LSX channel designator	"00" : channel LS0 "01" : channel LS1 "10" : channel LS2 "11" : do nothing to any LSX channel
sc1	Synchronization control for the designated LSX channel	"1" : add LEX byte to designated LSX channel "0" : delete last byte from designated LSX channel
sc0	Synch/eoc designator	"0" : perform synchronization control as indicated in sc7-sc1 "1" : this byte of current (even-numbered) frame and of frame that immediately follows is an eoc frame

No synchronization action shall be taken for those frames in which the "fast" byte is used for crc, fixed indicator bits, or eoc.

When the data rate of the C channel is 16 kbit/s, the LS0 sub-channel shall be transported in the LEX byte, using the "add LEX byte to designated LSX channel", with LS0 as the designated channel, every other frame on average.

7.2.2.2 Synchronization for the interleaved data buffer

Synchronization control for the interleaved data buffer can occur in frames 1 through 67 of an ADSL superframe as described in 7.2.1.1, where the "synch" byte may be used as the synchronization control byte.

The format of the "synch" byte when used as synchronization control for the interleaved data buffer is given in table 28.

Table 28 – Synch byte format for synchronization – Interleaved data buffer

Bit	Application	Specific usage
sc7-sc4	not used	set to "0" until specified otherwise
sc3, sc2	LSX channel designator	"00" : channel LS0 "01" : channel LS1 "10" : channel LS2 "11" : do nothing to any LSX channel
sc1	Synchronization control for the designated LSX channel	"1" : add LEX byte to designated LSX channel "0" : delete last byte from designated LSX channel
sc0	Synch/aoc designator	"0" : perform synchronization control as indicated in sc3-sc1 "1" : LEX byte carries ADSL overhead control channel data; a delete synchronization control may be allowed as indicated in sc3-sc1

No synchronization action shall be taken during frame 0, where the "synch" byte is used for crc, and the LEX byte carries aoc.

When the data rate of the C channel is 16 kbit/s, the LS0 sub-channel shall be transported in the LEX byte, using the "add LEX byte to designated LSX channel", with LS0 as the designated channel, every other frame on average.

7.3 Scramblers

The binary data streams output from the fast and interleaved buffers shall be scrambled separately using the same algorithm as for the downstream signal, specified in 6.3

7.4 Forward error correction

The upstream data are Reed-Solomon coded and interleaved using the same algorithm as for the downstream data, specified in 6.4.

7.5 Tone ordering

The tone ordering algorithm shall be the same as for the downstream data, specified in 6.5.

7.6 Constellation encoder – with trellis coding

Block processing of Wei's 16-state 4-dimensional trellis code to improve system performance is optional. If it is implemented, an algorithmic constellation encoder shall be used to construct constellations with a maximum number of bits equal to N_{upmax}, where $N_{upmax} \leq 15$.

The encoding algorithm is the same as that used for downstream data (with the substitution of the constellation limit of N_{upmax} for $N_{downmax}$), specified in 6.6.

7.7 Constellation encoder – without trellis coding

An algorithmic constellation encoder shall be used to construct constellations with a maximum number of bits equal to N_{upmax} , where $15 \geq N_{upmax} \geq 8$. The encoding algorithm is the same as that used for downstream data (with the substitution of the constellation limit of N_{upmax} for $N_{downmax}$), which is specified in 6.7. The constellation encoder does not use trellis coding with this option.